Nov./Dec. 1958
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Transistorized TV Receiver

Processing of Silicon

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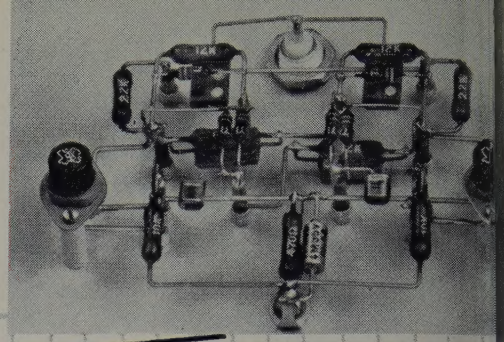

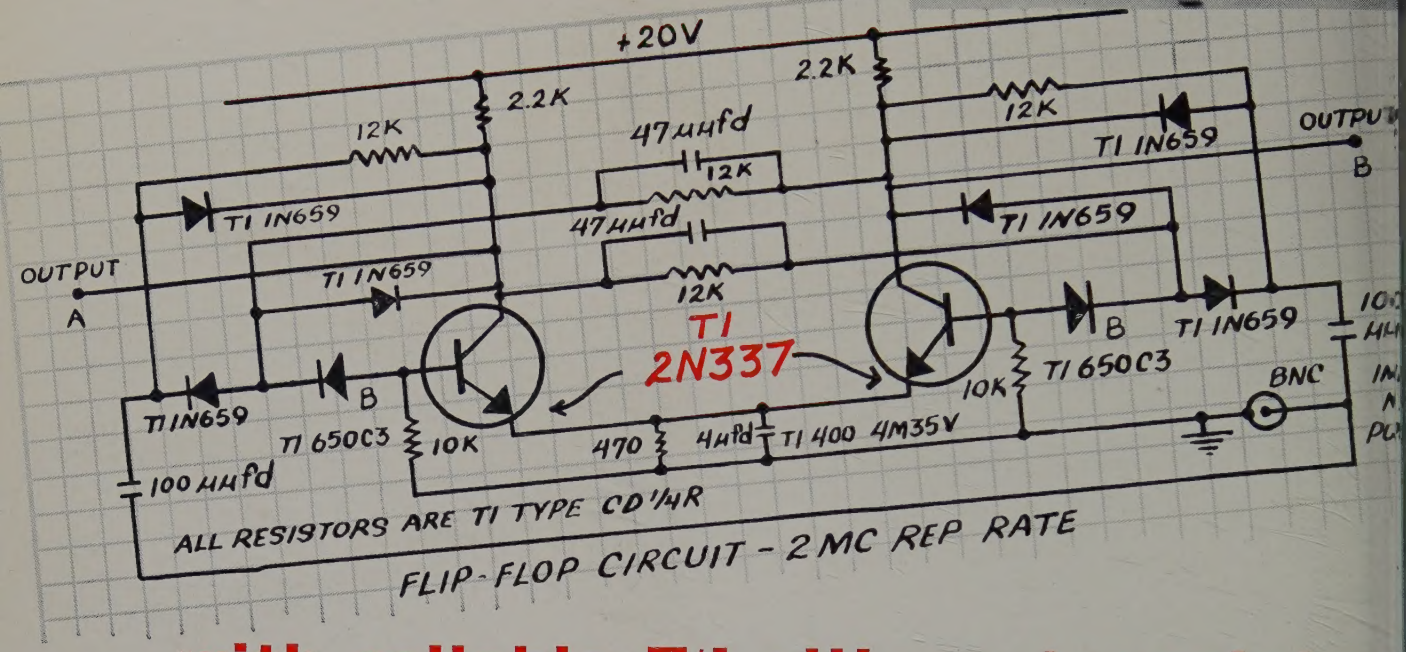

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	from	to
BV_{CBO}	40 V max	45 V max
R_{CS}	300 Ω max	150 Ω max
h_{ib}	90 Ω max	80 Ω max

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design characteristics at 25° C ambient (except where advanced temperatures are indicated)

		test conditions		2N337 min	2N337 design center	2N337 max	2N338 min	2N338 design center	2N338 max	unit
I_{CBO}	Collector Cutoff Current	V_{CB} = 20V	I_E = 0	—	—	1	—	—	1	μA
	at 150°C	V_{CB} = 20V	I_E = 0	—	—	100	—	—	100	μA
BV_{CBO}	Breakdown Voltage	I_{CB} = 50μA	I_E = 0	45	—	—	45	—	—	V
BV_{EBO}	Breakdown Voltage	I_{EB} = 50μA	I_C = 0	1	—	—	1	—	—	V
h_{ib}	Input Impedance	V_{CB} = 20V	I_E = −1mA	30	50	80	30	50	80	Ohm
h_{ob}	Output Admittance	V_{CB} = 20V	I_E = −1mA	—	0.2	1	—	0.2	1	μmho
h_{rb}	Feedback Voltage Ratio	V_{CB} = 20V	I_E = −1mA	—	200	2000	—	300	2000	X10⁻⁶
h_{fb}	Current Transfer Ratio	V_{CB} = 20V	I_E = −1mA	0.95	0.985	—	0.975	0.99	—	—
h_{FE}	DC Beta	V_{CE} = 5V	I_C = 10mA	20	35	55	45	80	150	—
$f_{\alpha b}$	Frequency Cutoff	V_{CB} = 20V	I_E = −1mA	10	20	—	20	30	—	mc
C_{ob}	Collector Capacitance*	V_{CB} = 20V	I_E = −1mA	—	1.2	3	—	1.2	3	μμf
R_{cs}	Saturation Resistance†	I_B ‡	I_C = 10mA	—	75	150	—	75	150	Ohm
h_{fe}	Current Transfer Ratio	V_{CB} = 20V	I_E = −1mA, f = 2.5mc	14	22	—	20	24	—	db
t_r	Rise time§			—	0.05	—	—	0.06	—	μsec
t_s	Storage Time			—	0.02	—	—	0.02	—	μsec
t_f	Fall time			—	0.08	—	—	0.14	—	μsec

* Measured at 1 mc † Common Emitter ‡ I_B = 1mA for 2N337, 0.5mA for 2N338 § Includes delay time (t_d)

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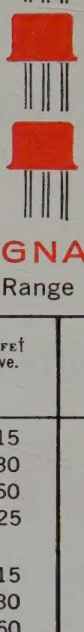

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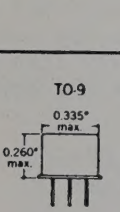

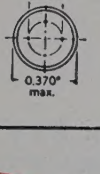

	Type	I_{EO} or I_{CO} at V_{CB} = 20 V_{dc} μA	V_{CE} max. volts	H_{FE}† ave.	r_b' f = 1Mc ohms	r_e kilohms	Noise Figure db (max.)	c_{ob} f = 100Kc ave. μμf	$f_{\alpha b}$ ave. Kc
PNP	2N327A	0.005	−40	15	1200	500	30	65	200
PNP	2N328A	0.005	−35	30	1400	500	30	65	300
PNP	2N329A	0.005	−30	60	1500	500	30	65	400
PNP	2N330A	0.005	−30	25	1300	500	15	65	250
NPN	2N619	0.005	50	15	2000	500	30	35	200
NPN	2N620	0.005	40	30	2500	500	30	35	350
NPN	2N621	0.005	30	60	2700	500	30	35	500
NPN	2N622	0.005	30	25	2400	500	15	35	300

†for PNP, I_B = −0.1mA; V_{CE} = −0.5V; for NPN, I_B = 0.5mA; V_{CE} = 1.5V

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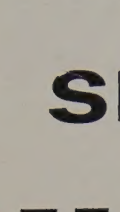

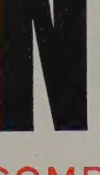

	Type	I_{EO} or I_{CO} at V_{CB} = 20 V_{dc} μA	V_{CE} max. volts	h_{fe}* ave.	h_{ie}* max. ohms	h_{oe}* max. μmhos	Noise* Figure db	c_{ob} f = 100Kc ave. μμf	$f_{\alpha b}$ ave. Kc
PNP	2N1034	0.005	−40	15	3000	70	30	65	200
PNP	2N1035	0.005	−35	30	3000	85	30	65	300
PNP	2N1036	0.005	−30	60	3000	100	30	65	400
PNP	2N1037	0.005	−35	30	3000	85	15	65	250
NPN	2N1074	0.005	50	15	3500	70	30	35	200
NPN	2N1075	0.005	40	30	3500	85	30	35	350
NPN	2N1076	0.005	30	60	3500	100	30	35	500
NPN	2N1077	0.005	30	25	3500	85	15	35	300

*V_C = 5V; I_E = 3mA

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Artist's conception of the use of transistors in satellites. Courtesy Western Electric Co. See page 17 in this issue.

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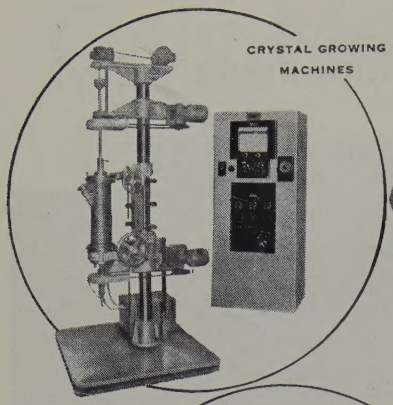
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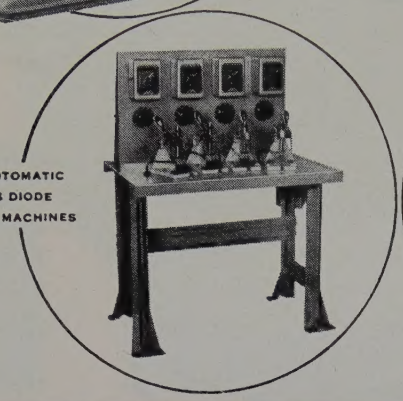
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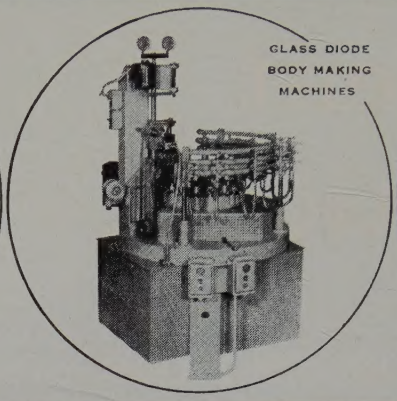
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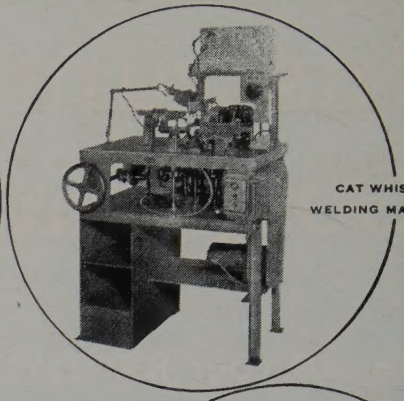
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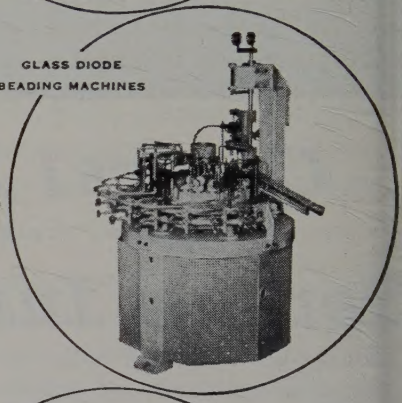
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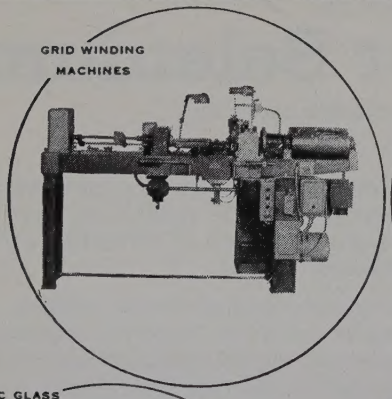
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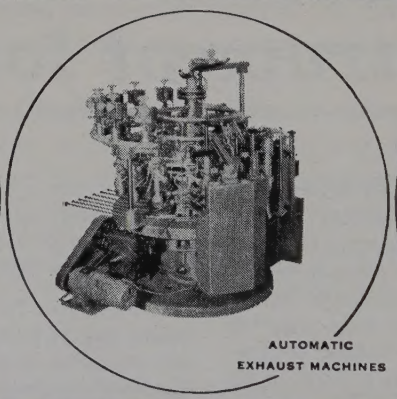
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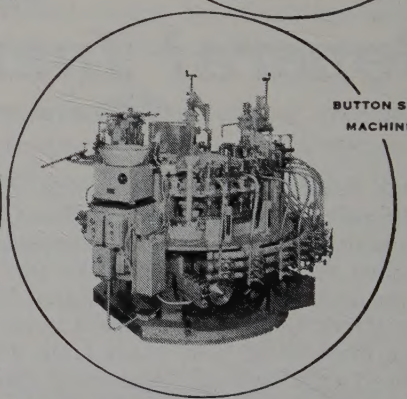
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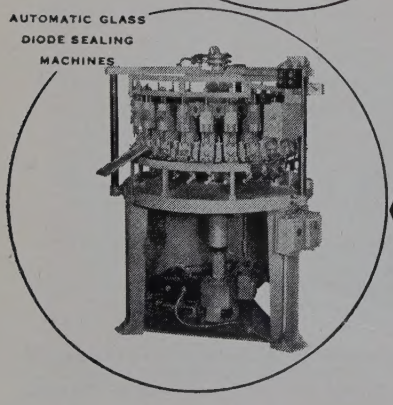
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Editorial . . .

Awards Announcement

SEMICONDUCTOR PRODUCTS magazine announces two awards, each consisting of a suitably engraved gold medal and $500. One is for the most outstanding article on semiconductor circuit design, and the other for the most outstanding nomograph relating to semiconductor circuit design. Details of these awards appear on page 22 of this issue.

Double Checking Patent Review

A few manufacturers and interested individuals have written to us regarding patent omissions in our first installment of Patent Review, and have provided us with additional items covering this and subsequent periods. For this reason, each month we will publish an addendum which will include omitted items, if any. We invite manufacturers and other individuals and organizations to submit to us lists of their patents for purposes of double checking our findings.

Highlights of National Electronics Conference

Topics of great interest treated at the 14th N.E.C. in Chicago on October 13, 14, and 15, 1958 were pulse generation, switching by diodes and by transistors, and photo-luminescent devices.

On pulse generation, two papers of particular interest were "Pulse Circuits Using Avalanche Transistors" by D. S. Gage, and "Transistor Magnetic Pulse Generator" by A. Krinitz. In the first paper, which described voltage punch-through and avalanche multiplication, it was shown that by utilizing both phenomena in ordinary transistors a very fast small pulse (4 millimicroseconds rise time) or a very large current pulse (30A peak, with about 0.1 usec rise time, peak power 200 W) could be obtained. In the second paper, a transistor magnetic pulse generator suitable as a radar modulator was described. The generator is a line type modulator consisting of a charging circuit and a pulse shaping circuit. Small size and reliable operation were achieved through the use of transistors and magnetic cores in place of bulky, inherently short-lived vacuum tube thyratrons.

With regard to switching, one of the most interesting papers from the point of view of applications was the one entitled, "Switching VHF Power with Semiconductor Diodes" by R. M. Mattson and S. H. Liu. The problem of switching radio frequency signals from a common input cable to various output cables at different times was discussed. The frequency used was 500 *mc* and the power involved was up to 10 W. Diodes were located close to a Tee connection to channel the flow of *r-f* power to different antennas by means of reverse or forward biasing.

On photoluminescent devices, three papers worthy of note were, "The Response of Germanium Phototransistor to Light Pulses of Very High Intensity and Short Duration" by R. Frerichs and E. Niuly, "Remotely Controlled Electroluminescent Totalizing Display" by R. C. Lyman, C. I. Jones, and A. Leger, and, "Lumistors, Their Applications and Their Limitations" by C. F. Spitzer.

The first paper discusses a newly discovered effect, namely, a "negative photo-effect" which is found to exist with the application of a single light pulse after the phototransistor is allowed to remain inactive for 24 hours. This effect consists of a conductivity decrease which is attributed to the presence of traps. From experimental verification, and using the volume energy band diagrams, the depth of these electron traps has been found to be 0.36 *ev*. The second paper described an automatic display consisting entirely of solid state devices. The system may be used to relay information, replace manually posted displays, summarize information, and operate as an input or output accessory for a computer. The third paper described a new category of active components which may be used in control systems. These devices are obtained by a suitable arrangement of electroluminors and photo-conductors. They have power gains of about 40 db, low cost, small physical dimensions, are practically two-dimensional with an area of about one in —2/ watt, and are easy to store and use. Present frequency response limitation is 100 cps; however, this value is expected to reach 5000 cps. Applications are visualized in servosystems, slow-speed logic circuits, and relays.

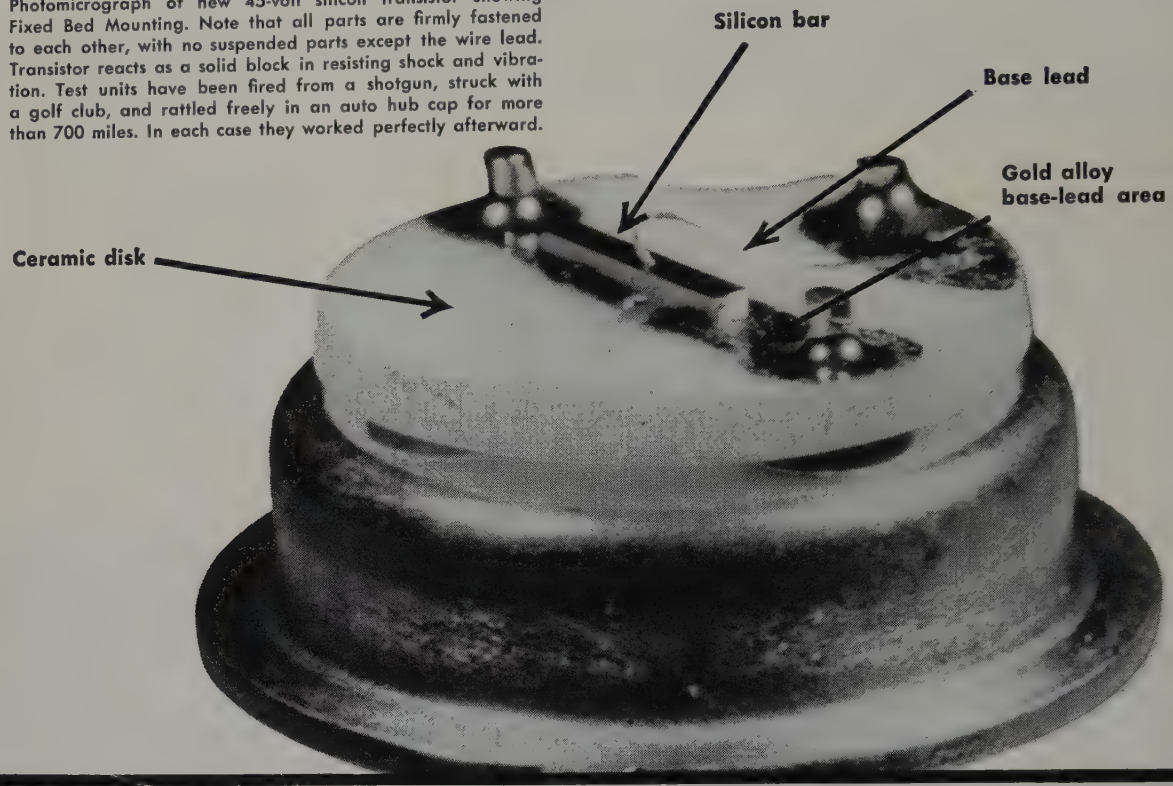
Index

An index of articles and other material published in SEMICONDUCTOR PRODUCTS during the year 1958 will appear in the January 1959 issue.

Samuel L. Marshall

New 45-volt silicon transistor absorb

Photomicrograph of new 45-volt silicon transistor showing Fixed Bed Mounting. Note that all parts are firmly fastened to each other, with no suspended parts except the wire lead. Transistor reacts as a solid block in resisting shock and vibration. Test units have been fired from a shotgun, struck with a golf club, and rattled freely in an auto hub cap for more than 700 miles. In each case they worked perfectly afterward.



20% safety factor announced for low-current silicon rectifiers

Designers who now apply their own safety factor to the published peak inverse voltage rating may avoid this step by using G-E low-current silicon rectifiers.

General Electric's PIV figures are set by allowing a 20% safety margin at −65°C. This margin is applied at the point of sharp breakdown voltage and increases with temperature until a maximum safety factor of 33% is reached at 150°C.

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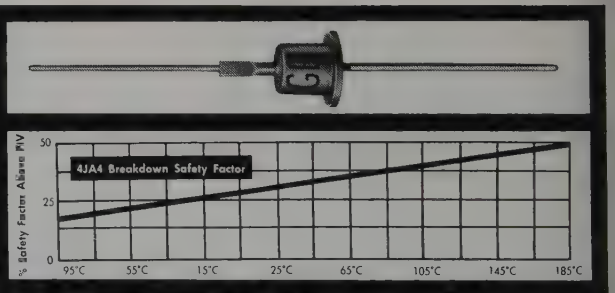

	Maximum Ratings and Specifications					
	PIV	RMS Voltage	Cont. Reverse D-C Volt	D-C Output (150°C Amb.)	D-C Output (50°C Amb.)	Ambient Operating Temp
1N536-40, 1N1095-96 series	50-600	35-420	50-600	250	750	165
1N440B series	100-600	70-420	100-600	300-500 (100°C)	300-750	150-165
1N1487-92 series	100-600	70-420	100-600	250 (125°C)	750 (25°C)	140
1N1692-95 series	100-400	70-280	100-400	250 (100°C)	600 (50°C)	115
	volts	volts	volts	ma	ma	°C

buse far beyond present specs—
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Nominal Electrical Characteristics at 25°C
(2N332-336 rated at V_{CB} = 5V; I_E = ma, f = 1kc;
2N337-338 rated at V_{CB} = 20V; I_E = 1ma, f = 1kc)

	2N332	2N333	2N334	2N335	2N336	2N337	2N338
nt Transfer Ratio	15	30	39	60	120	55	99
ha Cutoff iquency =5V; =1ma)	10	12	13	14	15	30	45mc
or Capacity 1 mc)	7	7	7	7	7	1.4	1.4 μμa
ctor Break- n Voltage 50 μa, I_E = 0)	45 min.	45 min.	45 min.	45 min.	45 min	45 min	45 min. volts
tor Satura- Resistance 2.2ma, =5ma)	90 200 max	80 200 max.	75 200 max	70 200 max	70 200 max.	75* 150 max	75** 150 max.
tor Current 30V, I_E = 0 5V, I_E = 0, 150°C)	.002 50 max	.002 50 max.	.002 50 max.	.002 50 max	.002 50 max	.002***	.002 μa max.***
non Emitter ent Gain DC beta 10ma)						20	45

*(I_B = 1ma, I_C = 10ma) **(I_B = .5ma, I_C = 10ma) ***(V_{CB} = 20V; I_E = 0)

This new series of high-voltage silicon transistors promises designers more reliable physical and electrical performance than ever before in amplifying and switching circuits. Fixed Bed Mounted transistors have been tested in some cases to more than twice present requirements—72 inch drop test instead of 30 inches, 1300 G shock test instead of 500—without evidence of failure.

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Manufacturers who have tested the first sample units report "extremely consistent parameters." Mechanically, Fixed Bed Mounting obsoletes all present standards of performance for silicon transistors. Test these remarkably reliable transistors yourself. Ask your G-E semiconductor representative for complete details.

lore G-E transistors meet Air Force specifications

Absolute Maximum Ratings (25°C)

ltages		
Collector to Base	V_{CB}	—45 volts
Collector to Emitter	V_{CE}	—30 volts
Emitter to Base	V_{EB}	—5 volts
llector Current	I_C	—300 ma
mperatures		
Storage	T_{STG}	Max. + 100°C Min. —65°C
Operating Junction	T_J	Max. + 85°C

D-C Electrical Characteristics (25°C)
(Design Center)

		USAF 2N43A	USAF 2N44A
rward Current Gain, Common Emitter I_C/I_B V_{CE} = —1V; I_C = —100ma)	h_{FE}	48	25

TYPES USAF 2N43A, USAF 2N44A

These are General Electric's familiar germanium audio PNP transistors which have been widely used in civilian applications for the past several years. If you are designing transistorized equipment for the military, remember that G.E.'s '43A and '44A meet military specifications.

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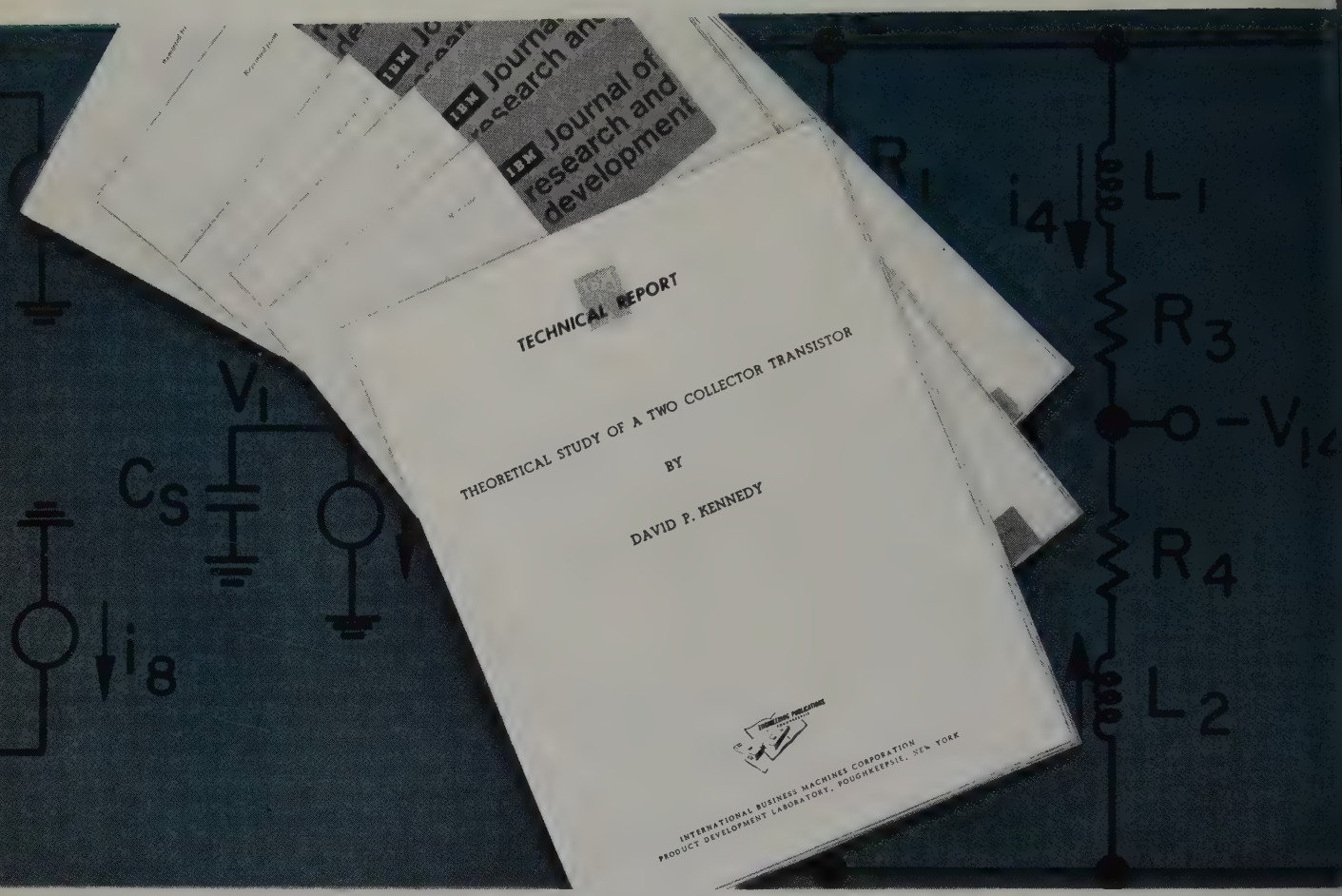

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Industry News

Factory sales of transistors in August attained the highest level for any one month in the history of that industry, the Electronic Industries Association announced. Unit sales of transistors during the first eight months of this year have nearly equaled the sales recorded by EIA during the entire calendar year 1957.

Factory sales of transistors in August totaled 4,226,616 with a dollar value of $9,975,935 compared with 2,631,894 transistors valued at $6,598,762 sold in July and 2,709,000 units valued at $6,598,000 sold in August a year ago.

Cumulative sales of transistors during the first eight months of this year, January-August, totaled 25,310,834 valued at $59,419,783 compared with 14,611,300 units with a dollar value of $42,063,000 sold during the corresponding eight-month period last year.

Factory sales of transistors during calendar year 1957 totaled 28,738,000 units with a dollar value of $69,739,000, according to EIA's compilation.

The following EIA chart shows factory sales and the dollar value of transistors in August and the first eight months of 1958:

	1958 Sales (units)	1958 Sales (dollars)	1957 Sales (units)
January	2,955,247	$6,704,383	1,436,000
February	3,106,708	6,806,562	1,785,300
March	2,976,843	6,795,427	1,904,000
April	2,856,234	7,025,547	1,774,000
May	2,999,198	7,250,824	2,055,000
June	3,558,094	8,232,343	2,245,000
July	2,631,894	6,598,762	1,703,000
August	4,226,616	9,975,935	2,709,000
TOTAL	25,310,834	$59,419,783	14,611,300

Beckman Instruments, Inc., announces formation of the Shockley Transistor Corporation as a subsidiary company to expand development and manufacture of specialized semiconductor components for electronic instruments, communications equipment and control systems. Dr. Arnold O. Beckman, president of the parent firm, said creation of the new unit marks successful completion of a two-year semiconductor development and pilot production program directed by Dr. William Shockley. Dr. Shockley's group has been operating at Palo Alto (Calif.) since 1956 as the Shockley Semiconductor Laboratory of Beckman Instruments, Inc.

Ultrapure silicon for the electronics industry is now in full-scale production in new $5 million facilities at the Cherokee Plant (Danville, Pa.) of Merck & Co., Inc. The new plant's capacity is in excess of 25,000 pounds per year, according to Dr. George Krsek, director of the company's Electronic Chemicals Division. Merck has been manufacturing ultrapure silicon in interim production facilities since early this year. Three forms are in production: polycrystalline billets, polycrystalline rods, and single crystal silicon.

The DATA-GAGE, previously manufactured by Texas Instruments as a fluid level data collecting system, has been extended to be applicable to any industrial use requiring both data collection and remote control of on-off devices. The transistorized system is composed of a Receiver Console Unit located at the central operating point; a Field Selector Unit that can read and control 100 locations or be cascaded to control 1000; a common Analog Input Unit for all analog output transducers, and the necessary transducers and control elements. Connection between the Receiver Console Unit and the Field Selector Unit may be by direct wire, telephone or radio link using a digital code for accuracy and reliability.

Four new germanium PNP alloy-junction transistors (2N670, 2N671, 2N672, and 2N673) intended for use in high-voltage, high-current pulse amplifier and switching circuits were announced on Aug. 1 by C. H. Warshaw, General Sales Manager of Philco Corporation's Lansdale Tube Company Division. These new transistors are immediately available in production quantities. The low thermal resistance inherent in Philco's new cold-welded all-copper JETEC-type case provides a high degree of reliability. This family of transistors further broadens the range of industrial and military applications. Typical uses are magnetic core switching, magnetic drum or tape writing, relay-actuating and large signal class B push-pull amplifying.

Entry of RCA into the silicon rectifier field was announced Aug. 22 by Dr. Alan M. Glover, Vice President and General Manager, RCA Semiconductor and Materials Division. "RCA's introductory products," Dr. Glover said, "consist of two developmental type silicon rectifiers of the diffused-junction type designed for use in the power supplies of TV and radio receivers, phonographs and other electronic equipment. Both types are in pilot production and are being sampled to the industry. Production quantities are expected to be available within sixty days.

A complete transistor training program which includes a classroom demonstration, circuit blocks that demonstrate nearly two dozen basic circuits with scores of variations, complete accessory kit, instructor's manual, and student's lab package is now made available by Philco Technological center.

Bendix Aviation Corp. announces a new diffused-alloy-power transistor called the Bendix DAP. In this transistor the diffusion technique is utilized in the application of impurity doping material to the emitter side of the germanium wafer. Performance standards claimed for this new transistor are: collector voltage ratings of over 100 volts, cutoff frequencies above 5 *mc*, collector currents greater than 30 amperes with extremely low saturation voltage drop (less than ⅛ of a volt,) and switching speeds less than ⅛ of a microsecond.

Ohio Semiconductors is now supplying configurations and semifabricated devices as well as bulk materials for electronic thermoelectric and infra-red application. Some of these semiconducting compounds are indium antimonide, indium arsenide, indium phosphide, gallium arsenide, lead telluride, bismuth telluride, and amorphous mixtures of these com-

[*Continued on page 55*]

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Making and Using the Satellite RF Transistors

W. C. PILKINGTON*
E. A. TEMPLE**
H. G. WELLS***

When satellite Explorer I was launched into its orbit, its radio transmitters became a vital source of information on the little moon's journey around the world. Since the satellite had limited space for circuitry and electronic components, transistors were chosen as the active electronic components. Transistors also have advantages in power economy, weight and ruggedness over tubes. Current transistors made at Western Electric's Laureldale, Pa. Plant, a facility sponsored by the U. S. Army Signal Corps, have achieved a maximum frequency of oscillation in the 1,000 *mc* range and have been used for *r-f* circuits in all U. S. satellite vehicles, including Explorer IV.

Although the Western Electric diffused-base transistors are available only to U. S. Military agencies and their contractors, a wide interest in them has been aroused. This article briefly describes their manufacture and discloses several applications, among which is the *r-f* portion of the Explorer I circuits.

THE PROTOTYPE of the diffused-base germanium transistors to be discussed was developed by the Bell Telephone Laboratories.[1] Production offsprings of the early type have undergone several modifications in structure, encapsulation and fabrication processes.

The basic process, gaseous diffusion, achieves uniform large-area junctions (for higher powers), very thin base regions with graded impurity concentrations (for short minority carrier transit times, including frequency enhancement due to accelerating "built-in" fields).

Manufacturing Diffused-Base Transistors

Assuming that *p-n-p* germanium units are to be made, a *p*-type crystal is used to start the fabrication process of the diffused-base transistors. After slicing, the slab containing 50 potential transistors is polished to a mirror finish.

The slabs are then etched with a variation of a CP-4 solution and then rinsed with distilled water. At this point the slab is .003″ thick. These slabs are placed in a hydrogen atmosphere furnace, where antimony is diffused into the surface. The furnace has a capacity of about 20 slabs. Diffusion occurs into the entire surface of the slabs to a depth of about 50 micro-inches.

The slab is now ready for fabrication of the emitter junction and base contact. This is accomplished by evaporation and alloying of aluminum and gold stripes on the slab through a mask, a rather ingenious as well as interesting process. *Fig. 1* is a simplified sketch of the action that takes place during the evaporation cycle. One evaporation process follows the other and the same slot in the mask directs each deposited stripe to its proper place, as can be seen in the sketch.

These evaporated stripes measure approximately 0.006″ by 0.001″ and have an 0.0005″ separation.

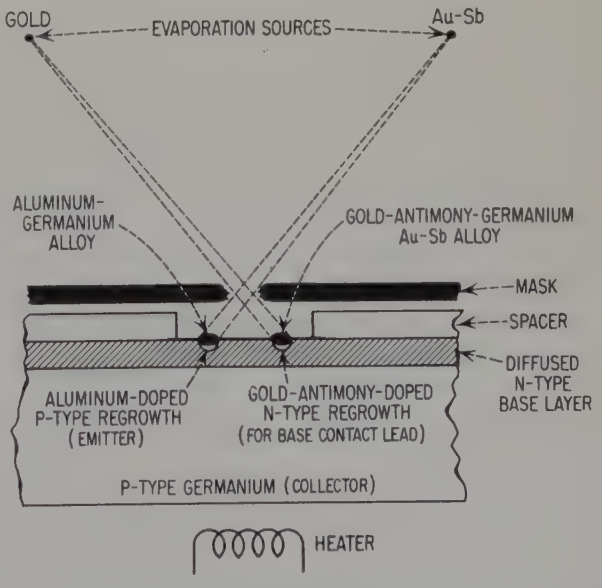


Fig. 1—Evaporation process through a mask is illustrated by sketch.

*Senior Research Engineer, Jet Propulsion Laboratory, Pasadena, California.

**Engineering Supervisor, Western Electric Company, Laureldale, Pa.

***Sales Specialist, formerly with Western Electric Co., New York; now with the Bell Telephone Laboratories, Murray Hill, New Jersey.

After the evaporation process, the slabs are scribed with a diamond point and broken into 50 wafers. The wafers are then put on headers, excess base material etched away, and leads are attached to the emitter and base contacts. The collector lead is attached directly to the header. Tubulated cans are then welded to the header. This is followed by baking under vacuum before back-filling with oxygen and sealing.

Each unit is then aged and tested to specified electrical characteristics. Because the units are tested for very high frequency performance requirements, special test equipment is used which was developed by the Bell Telephone Laboratories.

Two separately-coded diffused-base transistors are now in production, the 2N509 (previously called GF45015), and the 2N537 (previously referred to as GA-53194). The 2N537 is designed for oscillator service, although it has performed well in blocking oscillators and amplifier circuitry. The 2N509 is a higher gain type designed for *r-f* amplifier service. Experimental variants of these two types have been used in millimicrosecond switching service and show great potential in computer applications.

Basic typical characteristics of these units are as follows:

		2N509	2N537	
Breakdown Voltages:				
	BV_{cb}	—	1	Volts
	BV_{eb}	30	30	Volts
Alpha		0.97 (min.)	0.9 (min.)	
100 *mc* Common Emitter Current Gain	h_{fe}	15 (min.)	10 (min.)	*db*
Collector Power Dissipation:	P_c	200	200	*mw*

APPLICATION NOTES

General

The present production diffused-base transistors have a maximum frequency of oscillation in the 1,000 *mc* range and a collector power dissipation of 200 *mw*. Originally designed for oscillator service, selected units have performed well in *r-f* and *i-f* amplifiers, video amplifiers, fast switches, blocking oscillators and flip-flops.

Oscillator efficiencies of 44% are commonplace at 200 *mc* in a self-excited oscillator circuit. At ambient temperatures of 100°C oscillator efficiency drops to 32% with 200 *mw* input power.[2] Slightly lower efficiency occurs in crystal-controlled oscillator circuits using these transistors.

Device Application Considerations

Since higher transistor temperature means lower efficiency, the collector is electrically connected to the shell of the transistor and maximum efficiencies will be obtained by the use of a thermal heat sink connected intimately to some portion of the shell.

A "chimney" type heat sink of corrugated copper painted black has been used with these transistors, and when fitted closely to the periphery of the shell, operates effectively. A disc-type copper ring beneath the base of the transistor header, copper radiating fins, a banded copper stripe around the shell, or a clamped copper block with a snug-fit hole for the shell are all possible ways of increasing the heat dissipation. Use of the heat sink as an electrical circuit component, such as the plate of a capacitor, or a copper stripe inductance will tend to reduce the losses resulting from grounding the collector. One application for a push-pull oscillator has successfully used a line tank circuit made up of copper tubing of slightly smaller diameter than the shell of the transistor, expanded on the ends to form a force-fit on the shell of the transistors.

Commercial sockets are available for use with these transistors. Since most conventional sockets are significantly lossy above 100 *mc*, ceramic-supported collets are preferred for very high frequency circuits. Due to the high gains available at high frequencies, precautions must be taken to prevent parasitic and relaxation effects. These effects can be suppressed by adding unbypassed resistance in the emitter circuit or by loading the stage more heavily. Negative feedback may also be used to improve stability, but it requires special high-frequency components and strict attention to reactive effects.

Figure 2 shows a circuit which is used for determining the internal oscillation frequency, which is dependent primarily upon the internal lead inductance and the header capacitances. Most units show oscillation at 1,000 *mc* or above.

Circuit Considerations

Figure 3 shows simplified equivalent circuits for these transistors. The medium frequency circuit of *Fig. 3A* does not show the effects of space charge layer widening which ordinarily gives a common base feedback voltage ratio (h_{rb}) of 1-3 x 10^{-3}. In *Fig. 3A* the low frequency collector conductance (h_{ob}) is shown, but this is replaced in *Fig. 3B* by the collector series resistance (r'_c) which is more important in the high frequency range. In both equivalent circuits, collector barrier capacitance is separated from lead-to-lead capacitances of the header. These header capacitances are inherently high Q and reduce circuit bandwidth without affecting amplifier or oscillator efficiency while barrier capacitance enters directly into effi-

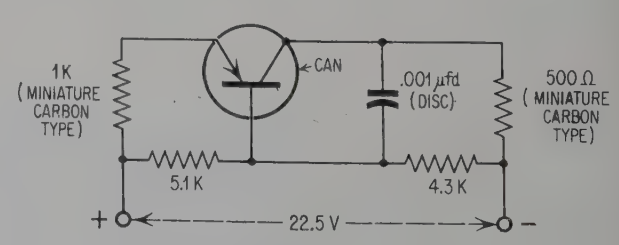


Fig. 2—Self-oscillation frequency test circuit.

ciency. For both of the equivalent circuits, the transfer current generator, αi_e contains an "excess phase" factor e^{-jmf/f_α}. The constant, m, is in the range 0.3-1.0 and is associated with the aiding fields in the base layer and the transit of carriers through the collector body.

Above 100 *mc*, noise figure increases with frequency asymptotically at the approximate rate of 6 *db* per octave due to gain reduction and transit and phase effects. At frequencies below 1 *mc*, noise figure increases asymptotically with decreasing frequency at approximately 3 *db* per octave because of (1/*f*) noise. *Fig. 4* shows typical noise figure variation with frequency for germanium diffused-base transistors.

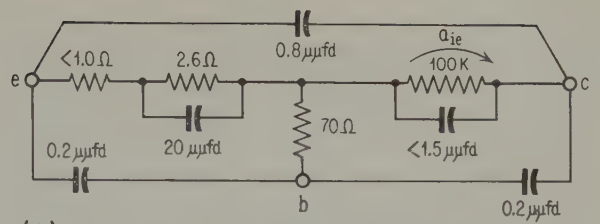
As with all high-gain high-frequency devices, good circuit design procedures should be followed to prevent parasitic oscillation and non-optimum operation. Care must be taken to keep an oscillator or power amplifier from becoming lightly loaded when the collector tank-tuning is subject to environmental variation. Conversely, heavy loading of the oscillator or amplifier, while sacrificing power efficiency, helps markedly to reduce parasitics and "squegging" or relaxation effects.

Another non-optimum condition is when the emitter is heavily driven by *r-f*. The emitter diode is driven into its reverse-biased state, and a sawtooth relaxation of a frequency determined by emitter average reverse resistances and effective capacitances modulates the carrier. An oscilloscopic presentation of the output after detection will indicate its presence. The introduction of a diode or an unbypassed resistance in the emitter circuit serves to prevent "blocking" the emitter when overdriven.

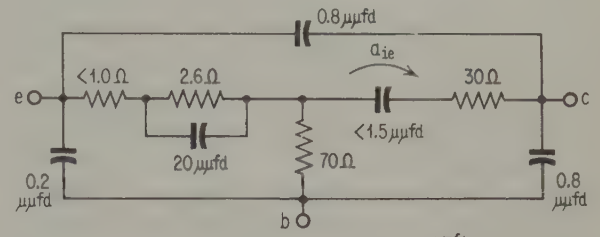
In cascading amplifiers following oscillators, it has been found desirable to couple circuits with a minimum number of components. In oscillators, capacitive coupling is to be preferred,[3] since transformer coupling contributes effects such as interwinding capacitance which may be detrimental. Conversely, link coupling from a power amplifier to a low-impedance transmission line is to be preferred, since loading can be controlled more effectively. Coupling networks such as *"L's," "T's"* or *"Pi's"* can be used effectively in special instances, but tend to increase the complexity of tuning and arriving at optimum circuit conditions.

Applications

A 200 *mc* self-excited oscillator is shown in *Fig. 5*. Power outputs of 100 *mw* have been realized with a collector input power of 200 *mw*. Nominal efficiencies are on the order of 40%. Short leads, shielding, and high-frequency components must be used. Mica-button and low inductance miniature ceramic capacitors are suitable. Silverplating is not mandatory for the inductors, but tends to prevent poor *r-f* connections. Optimum collector load impedance is nominally 1,500 ohms.



(A) (f<10 MC/S) MEDIUM FREQUENCY EQUIVALENT CIRCUIT



$f_\alpha = \sim 1000$ MC-1500 MC Where $\alpha = \dfrac{\alpha_0 \epsilon^{-j\, mf/f_\alpha}}{1 + j\, f/f_\alpha}$

(B) HIGH FREQUENCY APPROXIMATE EQUIVALENT CIRCUIT

Fig. 3—Equivalent circuits, at $I_e = 10$ *ma*, $V_C = -10$V

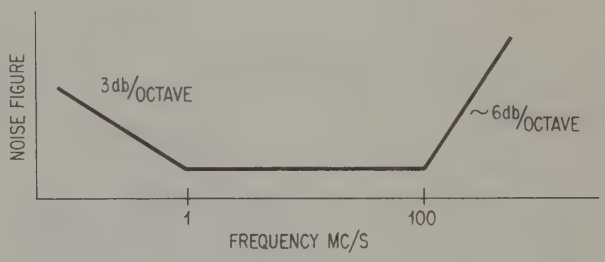
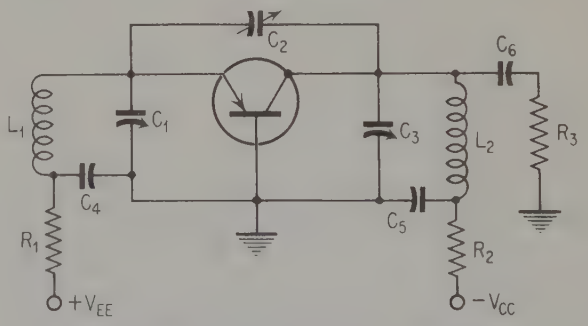


Fig. 4—2N537 typical noise figure asymtotes.



C_1, C_3 = 0.5-8.5 μμfd PISTON TYPE C_2 = 0.5-5 μμfd PISTON TYPE
C_4, C_5 = .002 μfd MICA BUTTON OR CERAMIC TYPE
C_6 = 500 μμfd MICA OR CERAMIC
L_1 = 1 μh, 2½ T. No.10, ½" DIA., Ag PLATE
L_2 = .067 μh, Ag PLATE, Cu STRAP (Q ≈ 600)
R_1 = 1000 Ω, ¼ W. CARBON R_2 = 110 Ω, ¼ W. CARBON
R_3 = EFFECTIVELY 1500 Ω AT 200 MC (CARBON, 2000 Ω)

Fig. 5—200 *mc* oscillator circuit.

Oscillator efficiency versus collector voltage and emitter current curves are shown in *Fig. 6* for a crystal oscillator operating at 100 *mc*. The collector-to-base breakdown voltage of this transistor (selected to be representative of the median oscillator efficien-

cies obtained) was 39 volts at 10 microamperes collector current. It is to be noted that increasing *d-c* collector voltage above approximately ½ BV_{cb} incurs an increasing loss of efficiency. Since the collector *r-f* voltage swings a minimum of 2 x V_{cc} (neglecting series resistances and reactances) the peak swing will drive the collector into breakdown when the *d-c* collector voltage is increased above roughly ½ BV_{cb}.

Figure 7 shows a flip-flop used in fast-switching non-frequency sensitive applications. Complete operation takes approximately 30 millimicroseconds. To obtain these switching times, the transistor must be kept out of saturation (i.e., $I_b = I_c/h_{fe}$, so that the transistor's inherently-poor reverse characteristics are not employed. Due to the transistor's unsymmetrical electrode geometry and impurity distribution, the reverse alpha is low (approximately 0.2), as is the reverse alpha frequency cutoff (approximately 1 *mc*). Thus the saturated storage and decay times are disproportionately large, as may be calculated from the defining equations derived by Moll[4] for storage and decay times. Since saturation contributes to these effects, the transistor must be kept from saturation to achieve fast-switching times. Since this implies a quasi-linear operation, a small-signal analysis is applicable. The circuit shown keeps the transistor out of saturation.

Figure 8 indicates an experimental blocking oscillator using miniature ferrite cup-cores. Operation at 10 *mc* and above is readily achieved. The critical components are the series resistance and the diode in the collector circuit. Since the voltage swing must be critically damped, the resistance must be adjusted to damp the oscillation to zero ($Q = 1$). However, in some applications a "ringing" effect with suitable shaping, can be used as a trigger for subsequent stages.

Figure 9 shows an experimental Class B power amplifier for 70 *mc*. Inputs are in series to facilitate balancing of the transistors. As a power amplifier, best biasing conditions seems to be with a slight positive voltage on the emitters.

EXPLORER I CIRCUITS

The block diagram of the two beacons used in Explorer I is shown in *Fig. 10*. One is a 60 *mw* (average power) transmitter while the other is a 10 *mw* (average power) transmitter.

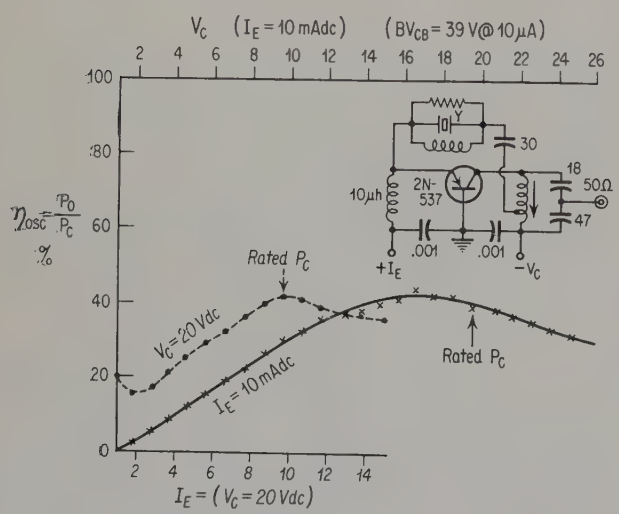


Fig. 6—Oscillator efficiency versus V_{CB} and I_E.

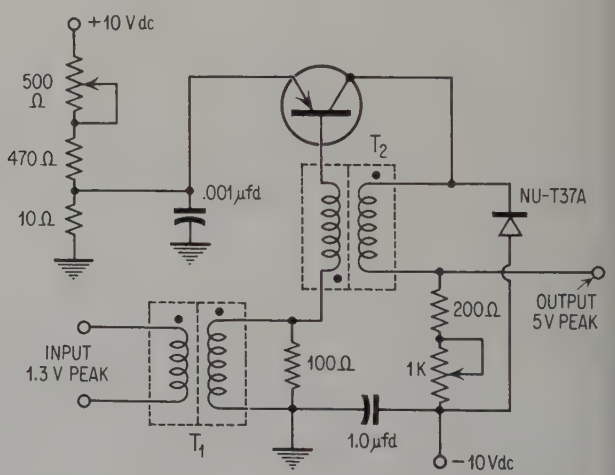


Fig. 8—Blocking oscillator circuit.

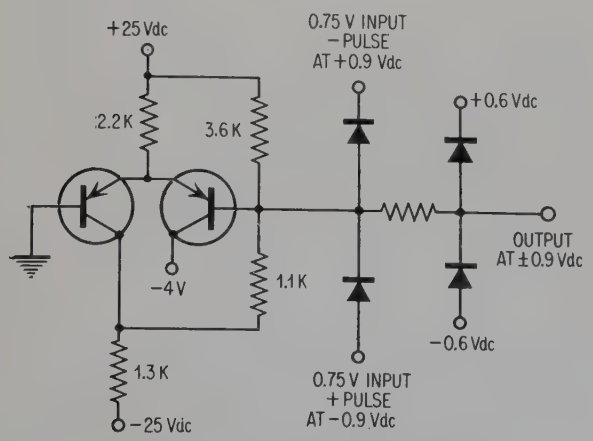


Fig. 7—Fast-switching flip-flop circuit.

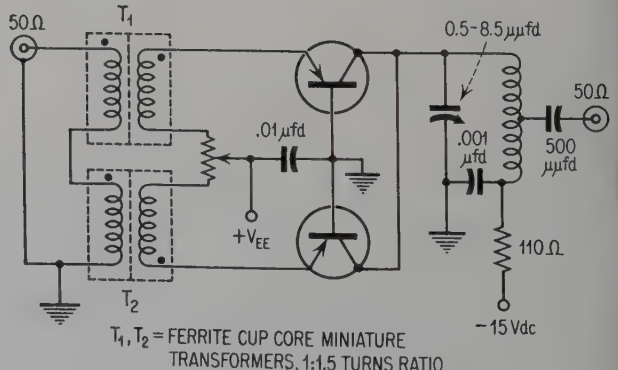
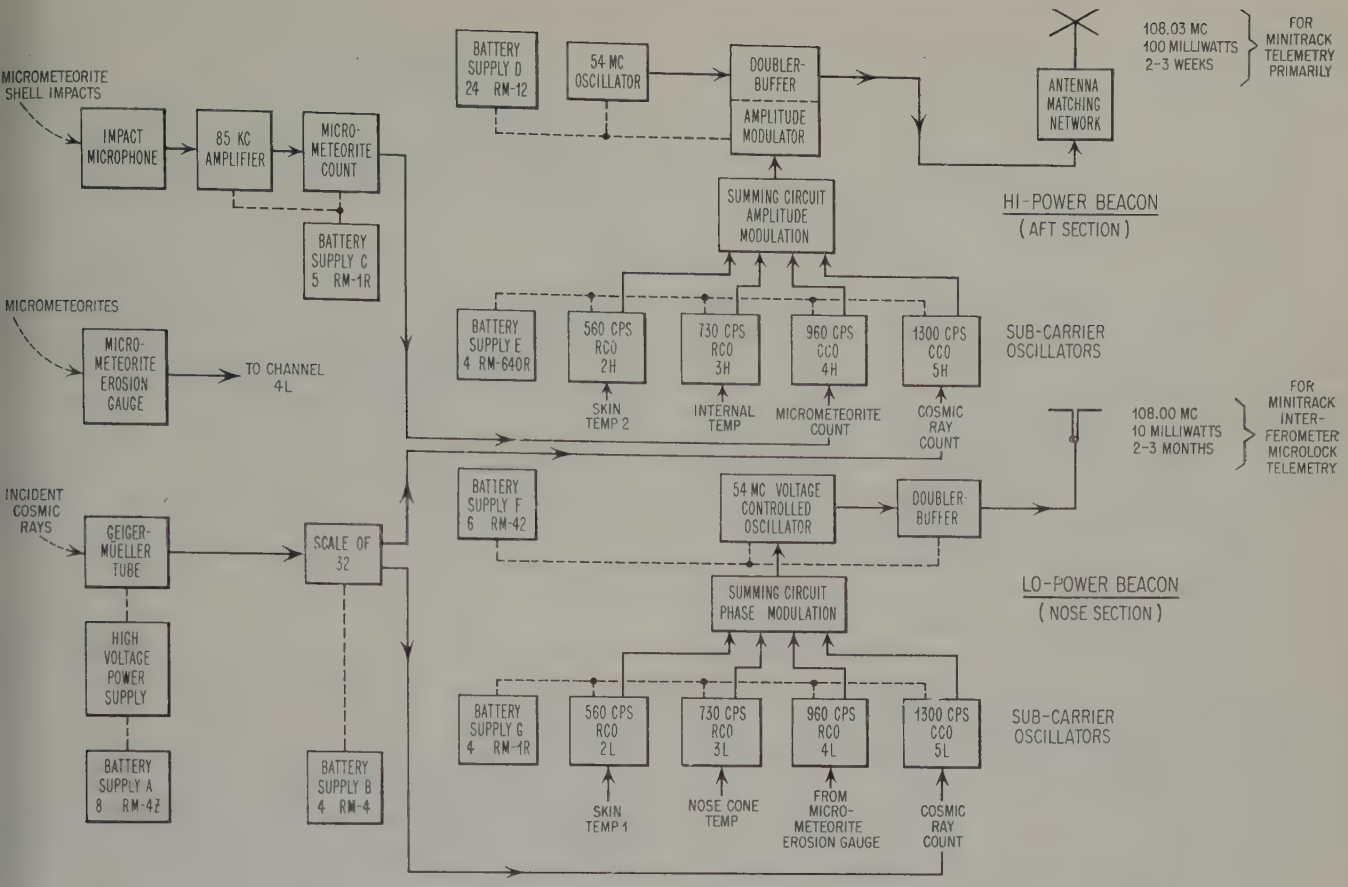


Fig. 9—Experimental circuit, class B amplifier, 70 *mc*.



	LETTER	NO. REQ'D	TYPE	PLACE
BATT. SUPPLY	A	8	RM-4Z	HV POWER SUPPLY
	B	4	RM-4R	SCALER
	C	5	RM-1R	85 KC AMPLIFIER
	D	24	RM-12	HI-POWER TRANSMITTER
	E	4	RM-640R	HI-POWER TRANSMITTER, SUB-CARRIER OSCILLATORS
	F	6	RM-42	LO-POWER TRANSMITTER
	G	4	RM-1R	LO-POWER TRANSMITTER, SUB-CARRIER OSCILLATORS

Fig. 10—Block diagram of Explorer I beacon circuits.

There are two antenna systems, two completely independent *r-f* oscillators, two double-buffers, the latter circuits using one transistor each. The purpose of the two transmitters is to have a redundant operation and to permit transmission of eight independent channels of information with phase modulated telemetering on one transmitter and amplitude modulated telemetering on the other.

On the left side of the diagram are the telemetering inputs, using standard *RDB* telemetry frequencies, channels 2, 3, 4, and 5. One is a micrometeorite impact channel which uses a microphone placed against the shell of the satellite as a transducer. The output of the microphone is amplified and counted and the output of the counter goes to channel 4 of the high-power transmitter where it changes the frequency of the beacon from near one end of the standard telemetry channel (centered at 960 *cps*) to near the other end.

Another micrometeorite input, which consists of several wire gauges that may be broken by meteorite impacts with sufficient momentum, is noted as an erosion gauge on the block diagram. All wired in parallel, the wire gauges go to a resistance oscillator. *Fig. 11* shows the gauges in position. This unit is attached to the motor case of the final stage of the satellite and is not on the payload shell.

Another input is a cosmic ray counter in which a Geiger-Mueller tube is used. The G-M tube output goes into a scale of 32 and the output of the scale of 32 is sent to channel 5 of the two *r-f* beacons. Channel 5 is centered at 1,300 *cps* and for every 16 counts of the G-M tube the scale of 32 changes state, and the output of the telemetry oscillator also changes from near one band edge to near the other band edge of the cosmic ray channel.

The other channels are all temperature measuring inputs. On the 60 *mw* beacon, channel 2 measures the

skin temperature and channel 3 measures an internal temperature, the latter actually being the temperature of the oscillator heat sink. The heat sink is a brass plate with a thermistor attached to it as the sensing element.

On the 10 *mw* beacon the other channels also measure temperature. Channel 2 performs a second skin temperature measurement. Channel 3, however, is a nose cone temperature measurement channel.

In both the low and high power beacons the output voltages from the telemetry oscillators are added in series. In the low power beacon the summed voltage is used directly to phase modulate the 54 *mc* oscillator. The phase modulation of the *r-f* oscillator stage is doubled in phase deviation in the output stage when the frequency is doubled. Channel 5 has about 14 degrees phase deviation while the other channels have a little less, on the order of 10 to 12 degrees.

Approximately the same summing of voltage signals occurs in the high power beacon. The summed voltage is amplified and used to amplitude modulate the *r-f* amplifier by variation of the collector voltage. A reasonable amount of phase modulation also occurs and can be used for reduction of the data, depending on the type of receiver used.

Acknowledgement

We wish to thank many of our colleagues at the Jet Propulsion Laboratory, the Bell Telephone Laboratories, and the Western Electric Company for their aid.

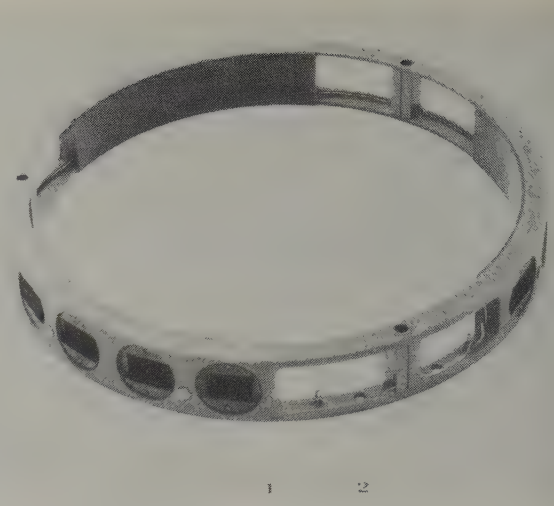


Fig. 11—Photograph of the micrometeorite erosion gauge of explorer I.

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4. "Large Signal Transient Response of Junction Transistors," J. L. Moll, *Proc. IRE*, Vol. 42, pp 1773-1783, Dec. 1954.

Editor's Note: Western Electric transistors mentioned in this article are available only to U. S. government military agencies and their contractors.

Semiconductor Circuit Design Award Announcement

Semiconductor Products Magazine announces that it will present two awards, one to the author of the most outstanding:

Semiconductor Circuit Design Article

and the other to the author of the most outstanding:

Nomograph Relating to Semiconductor Circuit Design

published in the April, 1959 to March, 1960 issues, inclusive, of Semiconductor Products. The award in each case will be:

A Gold Medal and $500.00

Entrees will be judged on the basis of:

USEFULNESS, ORIGINALITY, INGENUITY, and SCIENTIFIC VALUE

In addition to being eligible for the above awards, authors whose entrees are published will be paid in accordance with our regular scale for such articles. It is suggested that articles be limited to 3,000 words or less, exclusive of illustrations and diagrams. The latter need not necessarily be inked or ruled. They must however be neat and legible.

Further details and rules will appear in the January 1959 issue.

A Transistorized Television Receiver

ROGER R. WEBSTER*

This paper describes the circuitry of a small, portable, battery-operated television receiver. A modified 9-inch, 70° picture tube requires modest heater and deflection power. Total set power consumption is about 8.5 watts. Twenty-four transistors, fourteen diodes and one high-voltage rectifier tube accomplish all functions. All transistors are currently available, although some selection is required particularly for the tuner and horizontal deflection circuits.

INTEREST in transistorized TV receivers has been increasing as suitable devices become more available. A completely portable battery-operated receiver has much appeal, while the possibility of increased reliability in power-line operated sets has interested many manufacturers. Most of the major manufacturers are actively developing transistorized TV sets. Many have had sets operating for some time, some of which are more advanced than the set to be described here. Since few details of these sets have been released, a complete description of a transistorized receiver is of general interest. Texas Instruments, a major transistor supplier, has been interested in the application of transistors to TV for some time. Consequently, a program to study feasibility, device requirements, and circuits was undertaken; however, TI has no plans for the manufacture of such a set.

General Characteristics of Set

The set to be described was built into an existing commercial TV cabinet. The size is 8″ high by 9-1/2″ wide by 14″ long. Weight, including battery, is 19 pounds. The circuit uses 24 transistors, 14 diodes and one high-voltage tube rectifier. A 9QP4 picture tube, modified with a 12-volt 150-ma filament, was selected because the 70° deflection angle requires reasonably low deflection power. Power is supplied from a 10-cell 12-volt nickel-cadmium battery with a discharge life of about 6 hours at 700 *ma.*

The tuner and horizontal deflection circuits required by far the most effort, with the i-f amplifier next. As a consequence, the vertical deflection circuit has had less attention than it deserves, and vertical linearity is marginal.

Tuner

Tuner Performance—Adequate selectivity at the signal frequency, and lowest achievable noise figure are the fundamental tuner requirements. Gain is thus of secondary importance, and if the first two are achieved at low tuner gain, then the additional gain required can ordinarily be obtained in the *i-f* amplifier.

Noise Figure of r-f Amplifier vs Mixer—The noise figure of a transistor *r-f* amplifier has been compared with the same transistor as a mixer. The measured results show little or no difference between the two. For this reason, the inclusion of an *r-f* stage will inevitably increase the minimum achievable noise figure. Deleting the *r-f* stage will not necessarily improve the noise performance, however, since the frequency-selective circuits must be placed between the signal source and the input to the mixer. Insertion loss in the tuned circuit will add directly to the noise figure.

The insertion loss of a tuned circuit is directly related to the element *Q's. Fig. 1* shows a plot of insertion loss

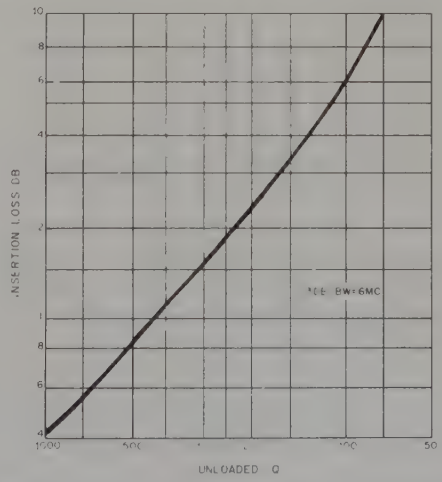

Fig. 1—Insertion loss as a function of a unloaded *Q* for a double tuned critically damped coupled network at 213 *mc*, (channel 13).

*Texas Instruments Incorporated, Dallas Texas.

at channel 13 *vs* unloaded *Q's*. Since typical coil *Q's* may run between 100 and 150 at this frequency, the insertion loss of a tuned circuit using coils may be as high as 6 *db*, which will certainly degrade the noise performance.

If designed properly, short segments of parallel lines have *Q's* of 500 or more and an insertion loss of 1 *db* or less.

Mixer Circuit Requirements—For good conversion gain, freedom from spurious responses, and minimum regeneration, the external impedance in both the base and emitter should be low at the intermediate frequency. For low oscillator power, they should be low also at the oscillator frequency. Parallel-tuned circuits are thus indicated because of their low impedance away from resonance. Special measures are sometimes required to avoid unwanted resonances.

Local oscillator power in the mixer depends on the type of transistor used. The 2N623 diffused-based triode mixer requires about 300 μwatts, while the 3N25 tetrode requires about 60 μwatts. Noise figures for selected 2N623 transistors are 9 to 11 *db* at channel 13, while the noise figure of the tetrode runs from 12 to 14 *db*.

Description of Tuners—Two tuners have been built for the TV set. One is a tetrode tuner using three selected 3N25 transistors for *r-f*, mixer, and local oscillator. The second uses two selected 2N623 as mixer and local oscillator. The tetrode tuner has about 20 to 22 *db* gain, with a 14 *db* noise figure at channel 13. Since the triode tuner has a lower noise figure, the tetrode tuner is not presently being used.

The triode tuner schematic is shown in *Fig. 2*. Since the 2N623 has little or no gain at channel 13, it is completely unsuited as an *r-f* amplifier. Although the tetrode could be used, its noise figure averages about 3 *db* higher than the triode so that it does degrade tuner performance. Therefore, the triode tuner uses no *r-f* stage. The input circuit uses short line segments instead of coils to keep insertion loss low at the high channels. The local oscillator and mixer transistors are selected primarily for low base resistance. Limit units with maximum base resistance will perform poorly, if at all, in the tuner.

The conversion gain of the 2N623 is 10 to 12 *db* at channel 13. The necessary local oscillator power (300 μwatts) is not available from either the 3N25 tetrode or the 2N623 at 257 *mc*. However, some 2N623's will give this much power as a low-side (170 *mc*) channel-13 local oscillator. As a result, a combination of high-side local oscillator on low channels (2 to 6), and low side on the high channels (7 to 13) is used. More suitable local oscillator transistors are already available and should eliminate this makeshift local oscillator arrangement.

The Intermediate-Frequency Amplifier

The *i-f* amplifier in this set was designed primarily for the triode tuner. Therefore, more gain is required than for the tetrode tuner and the bandpass must be symmetrical to accommodate the combination high-low local oscillator injection. Between 70 and 75 *db* gain is provided in five stages, so that the overall set gain from input terminals to second detector is about 85 *db*. It is a little difficult to convert power gain to signal gain, but 100 μvolts at the 300-ohm antenna will give approximately 1 volt peak at the second detector.

The *i-f* amplifier schematic is shown in *Fig. 3*. It will be noted that all of the tuned interstages except the one between the third and fourth *i-f* are synchronous single-tuned circuits set for miximum band width (i.e., no external shunt capacitors have been added). The interstage between the third and fourth *i-f* is an over-coupled double-tuned circuit, designed to give an overall flat transmission characteristic in the *i-f* pass band. Synchronous tuned stages give maximum gain and are readily aligned, while the bandpass characteristics are easily controlled in the one double-tuned circuit.

Agc is supplied from an *agc* rectifier, *D4*, operating on the sync peaks. The output of the *agc* detector is amplified in a *d-c* stage, *Q10*, and applied to the base of the first and second *i-f* stages. Supplemental diode loading on the input of these stages tends to minimize bandwidth changes as *agc* action reduces transistor current and raises transistor input impedance. Neutralizing capacitors on the first two stages are selected for minimum feed through at maximum *agc* rather than best neutralization.

The 2N623 is capable of an output of 20 *mw* or more on sync peaks, but not strictly as a class-A amplifier. To prevent shifts in the output stage operating point during high-level modulation (sync peaks), both emitter and base are by-passed very heavily and the customary decoupling resistor in the collector is replaced by an *r-f* choke.

It is possible to swing the output collector nearly the full battery supply voltage. However, to keep side effects down, the output stage is fully loaded by the second-detector diode and *agc* is set to hold the video output to 3 volts on sync peaks. At this relatively high

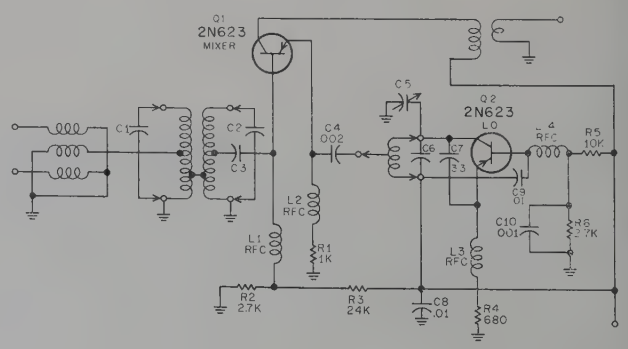

Fig. 2—Schematic of the triode tuner.

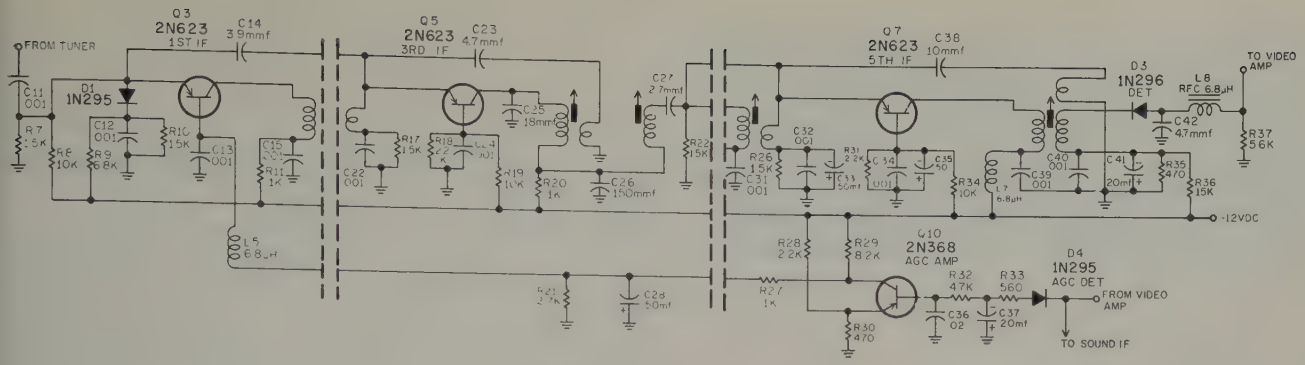

Fig. 3—Schematic of video i-f amplifier.

level (for transistor *i-f* amplifiers), the second-detector diode operates in essentially a linear manner over the entire video signal. A biasing network, *R35, R36, C40, C41,* provides a small initial forward bias on the second detector and video amplifier and improves linearity at very low levels.

Video Amplifier

A two-stage video amplifier consisting of an emitter follower driving a common-emitter output stage is shown in *Fig. 4.* The amplifier provides sufficient gain to drive the output stage to its full swing of 40 volts from a one-volt peak video signal. Video-amplifier bandwidth is about 2.7 *mc.* The video amplifier is direct coupled from the second detector to the output stage for the following reasons. First, the full video output may be obtained without distortion, since the *a-c* and *d-c* loading on the second detector are the same. Second, the bias networks and coupling capacitors are eliminated. Third, the average dissipation of the direct-coupled output unit is less than that of a fixed-bias stage. This follows, since with fixed bias, the transistor dissipation is greatest at no signal, whereas with direct coupling it is very low with no signal. At maximum signal, the dissipation is approximately the same for the two cases and is about one-half the zero-signal dissipation of a fixed-bias amplifier. The *d-c* coupling could be carried to the picture-tube input. However, the black level is not constant with varying signal levels, and the resulting change in picture brightness is annoying in certain conditions. Hence, the output is capacitor coupled.

Sync Circuits

Fig. 5 shows the sync circuits, which are similar to conventional vacuum-tube circuits. The composite video with positive-going sync at the collector of the first video amplifier, *Q8* is fed to a self-biased *n-p-n* clipper, *Q16.* About 0.75-volt peak-to-peak video, which is less than a minimum usable signal, will drive the clipper from cutoff to saturation.

Horizontal sync pulses are obtained at the emitter of the sync amplifier, *Q17,* while vertical pulses are obtained at the collector. *R72-C64* comprise the vertical integrator. A vertical isolation amplifier, *Q18,* is provided, whose primary purpose is to prevent feedback of the large vertical blocking oscillator signal into the horizontal sync system. Such feedback results in displacement of the top of the picture and poor interlace.

The horizontal *afc* system is similar to conventional vacuum-tube circuits, modified to accommodate the lower transistor impedances. A *d-c* amplifier, *Q21,* is included to give sufficient gain without undue loading of the horizontal output.

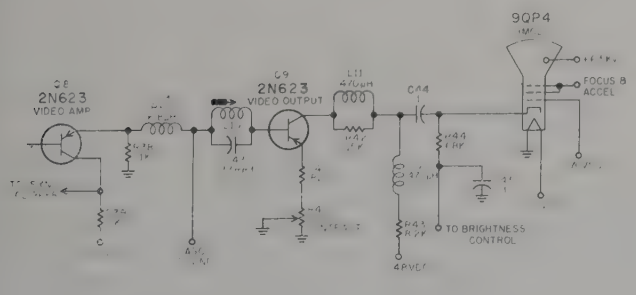

Fig. 4—Video amplifier.

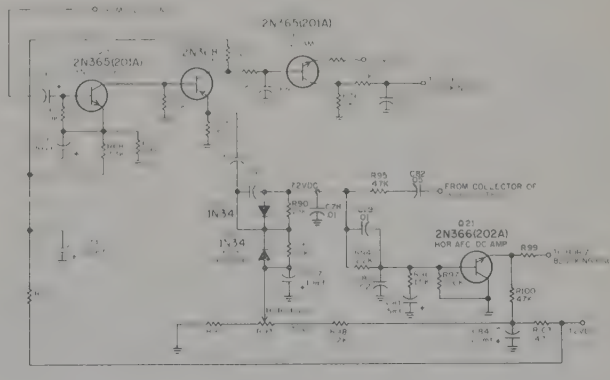

Fig. 5—Sync circuit and horizontal *afc*.

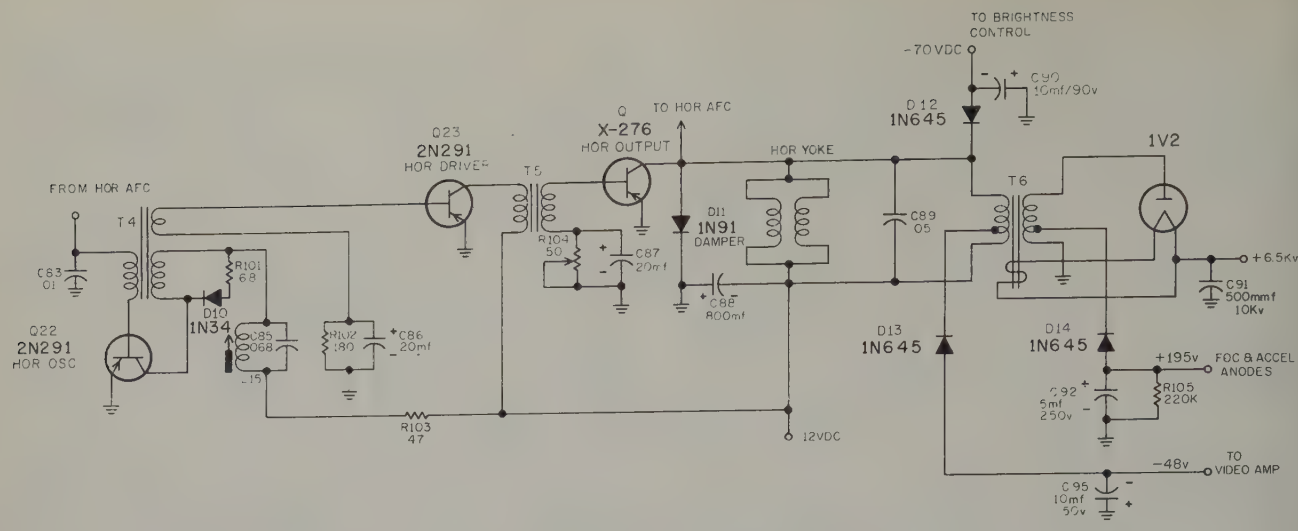

Fig. 6.—Horizontal deflection and high voltage circuits.

Horizontal Deflection and High Voltage

The horizontal deflection circuit, shown in *Fig. 6*, is similar to circuits described in the literature.[1]

The 9QP4, a 70° deflection tube, requires a horizontal deflection current of about 2 amp peak in the Sickles 150-μhy yoke. All of this current is flowing in the horizontal output transistor, *Q24*, at the end of each horizontal scan. Selected alloy-junction audio power transistors can be turned off in 2 microseconds with 10 to 15 x 10^{-6} watt-second per cycle drive power to the base. This amount of power is not readily available from the blocking oscillator, *Q22*. Thus, a horizontal driver, *Q23*, is included. The turn-off time of the output transistor may be shortened with more drive power and its efficiency increased. However, the drive power requirements go up faster than the output-stage power decreases when the turn-off time is less than around 2 micro-seconds (the exact time depends on the transistors used). These figures represent about the optimum with the selected 2N458 (X-276) audio power-type transistor. The efficiency of the driver is considerably better if the driver is turned off during retrace rather than turned on, because the driver peak current is reduced by a factor of about 5. The energy to turn off the output transistor is then derived from the magnetic field of the driver transformer. Assuming an efficiency of energy conversion of 50%, the driver-transformer inductance is set by the energy equation and the available supply voltage:

$$P = 1/2\ LI^2 \qquad (1)$$

$$E = L\ \frac{dI}{dt} \qquad (2)$$

The primary inductance of the driver transformer in this receiver is about 5 *mhy* with a 5 to 1 turns ratio.

The horizontal output transistor has the most severe requirements of any in the set. Not only must it switch off from 2 amps in a few microseconds with reasonable drive power, it must also be capable of withstanding up to 120 volts during horizontal retrace.

The high breakdown voltage requirement of the output transistor may be reduced by resonating the high-voltage flyback transformer to the second harmonic of the retrace cycle and by slowing the retrace. These schemes will also improve the *d-c* efficiency considerably.

The action of the flyback transformer resonance is shown quite clearly in *Fig. 7* which depicts the voltage at the horizontal output collector. The pronounced flat top is caused by flyback resonance at second harmonic. Peak voltage is reduced by this expedient to about 85 or 90 volts. Resonating the flyback in this fashion causes the high-voltage regulation to be poorer than normal. High voltage drops from about 6.9 *kv* at minimum brightness to about 6.1 *kv* at maximum brightness.

The retrace time of the set described is about 12.5 μsec and the resonant frequency of the flyback transformer is 90 to 95 *kc*.

The high-voltage rectifier, a 1V2, is the only vacuum tube in the set except for the picture tube. Although high-voltage semiconductor diodes have been used in this circuit, the ones examined were relatively slow. As a result, the *d-c* efficiency and regulation were both poorer than with the tube rectifier. Using a vacuum-tube rectifier causes no circuit complication, so that the solid-state rectifier does not appear to be justified at the present time.

The horizontal output and high-voltage transformer also supply *d-c* voltages for the video amplifier (—48 volts), brightness (—90 volts), and focus (+200 volts). These are obtained from suitable taps at the primary and secondary of the flyback transformer. Current drain of the entire horizontal deflection circuit is about 375 *ma* for an average picture brightness.

Vertical Deflection

The vertical deflection circuit is similar to one

which has appeared in the literature.[2] The circuit is shown in *Fig. 8*.

A blocking oscillator, *Q19*, drives the vertical output transistor, *Q20*, which is direct coupled to the vertical yoke. Direct current shift of the picture due to the *d-c* component of current in *Q15* is largely eliminated by shunting inductor *L14* across the yoke. *C68-R82* form a feedback circuit to improve linearity. The circuit suffers from marginal linearity and a large amount of interaction between the size, linearity, and bias controls. Current drain of the complete vertical deflection circuit is approximately 175 *ma*.

Sound

The schematic of the sound amplifier is shown in *Fig. 9*. A two-stage 4.5-*mc* amplifier provides sufficient gain for a ratio detector. The ratio-detector performance is improved considerably by operating into the relatively high impedance of the reflexed emitter follower, *Q12*, rather than a conventional common-emitter stage. A diode, *D5*, in the collector to the first *i-f* amplifier provides some limiting on strong signals. The audio amplifier is conventional. Maximum output is 0.5 watt.

Transistors for Larger Picture Tubes

The greatest problem in applying transistors to larger picture tubes is the power required for deflection. Deflection power is approximately proportional to the high voltage applied and to the cube of the deflection angle, if tube and yoke geometry remain conventional. If high voltage is increased from 6.5 *kv* in the present set to 13 *kv*, and deflection angle from 70° to 110°, the peak-to-peak horizontal deflection current will be raised from 4 *amp.* to around 30 *amp.* The horizontal output transistor will pass 18 to 20 *amp.* peak. The transistor must still be turned off in a few micro-seconds. Power supply regulation may be a serious problem. Even with high efficiency, power requirements will be high, so that a battery-operated set does not appear too practical for conventional large high-deflection-angle picture tubes.

Special picture tubes with reduced deflection requirements, increased yoke sensitivity, and special circuits may reduce large tube requirements to the point where portable operation is feasible. The overall power consumption of such a set would certainly be a small fraction of present *a-c* operated sets.

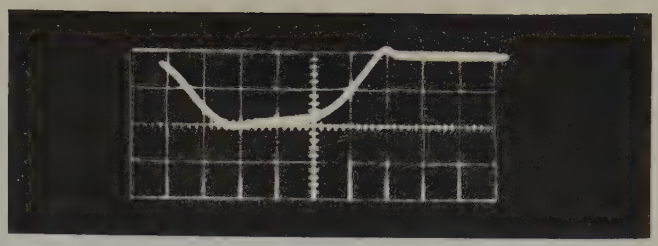

Fig. 7—Horizontal output collector voltage waveform.

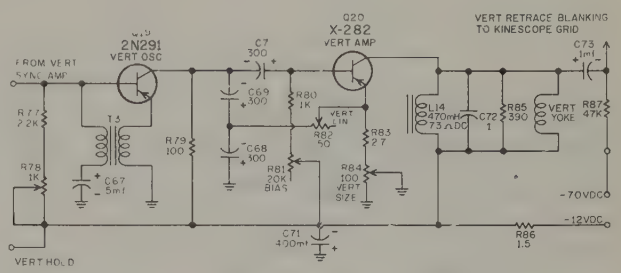

Fig. 8—Vertical deflection circuit.

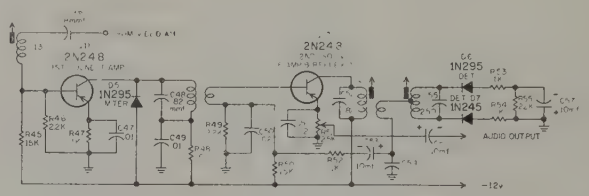

Fig. 9—Sound *i-f* amplifier.

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(1) Goodrich, H. C., "A Transistorized Horizontal Deflection System". RCA Review, September, 1957.

(2) W. Palmer and C. Schiess, "Transistorized Vertical Deflection System". Electrical Design News, May, 1957 (Abstract)

A High Accuracy h_{FE} Measuring Technique

CARL D. TODD*

EXACT TRANSISTOR circuit design is very complex and requires the knowledge of many device parameters. However, for most general engineering design work, there are several basic parameters which may be used to give excellent design approximations. Assuming that the transistor type selected has the voltage breakdown characteristics which will permit its use in the designer's circuit, it is necessary to know (1) frequency response characteristics, (2) input impedance, and (3) gain characteristics. In many low to medium speed switching applications, push-pull output stages, *d-c* amplifiers, and other applications, the parameter of major interest is the *d-c* current gain. This is more properly called current transfer ratio but the use of the term gain is widespread.

Since most of the circuits are of the common emitter configuration, it is desirable to know the value of h_{FE}, the *d-c* current gain in this configuration. By definition, this is the ratio of the collector current to the base current for some given operating point. It is somewhat standard practice at the present time to specify the collector voltage, V_{CE}, and the collector current I_C.

Present methods of measuring h_{FE} use the simple and straightforward circuit of *Figure 1*. Here, a fixed collector voltage is applied and a current I_B is applied to the base circuit and increased until the desired collector current is reached. The value of h_{FE} is then computed by dividing the value of I_C by I_B. Possible sources of error are (1) V_{CE} reading, (2) I_C reading, (3) I_B reading, and (4) error in computation. The error in the value of h_{FE} due to an error in V_{CE} is quite small unless measurments are made in a

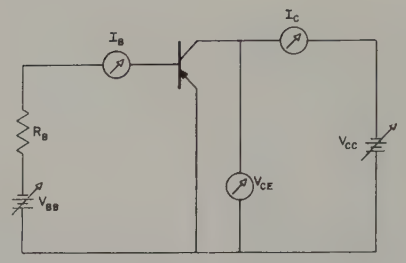

Fig. 1—Simple circuit for measuring h_{FE}.

condition where h_{FE} is collector voltage dependent. For most cases, V_{CE} measurement is within 4 percent including meter reading error. This normally means an error in h_{FE} of less than 0.5 percent.

The error in the measurement of I_B and I_C is roughly 4 percent each including meter errors and meter reading errors. Since the final calculation of h_{FE} involves the division of I_C by I_B, the quotient may have a maximum percentage error which is the sum of the two individual errors.

In addition to the error in the quotient due to inaccuracy in I_C measurement, there will be an additional error due to the difference in operating point. If a transistor has a good h_{FE} versus I_C characteristic, the error will be quite small for most of the range. However, if the transistor has a poor h_{FE} versus I_C characteristic, the error will be much greater. A reasonable error in h_{FE} due to I_C point is 1.5 percent.

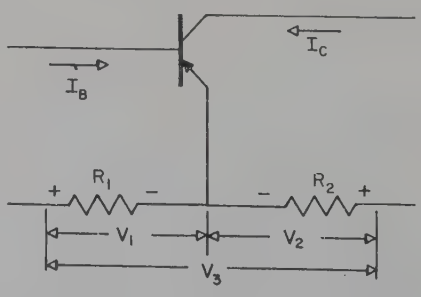

Fig. 2—Basic circuit for measuring h_{FE} by the use of resistors.

Finally, there is a possible error in the computation of h_{FE} of roughly 1 percent to 2 percent. Assuming the worst possible case in which all possible errors add, the total error in the measurement of h_{FE} is 12 percent. The root mean error is 6.2 percent.

If some means could be found to eliminate the errors resulting in the quotient of I_C divided by I_B and the calculation error, this would decrease the total possible error by roughly 10 percent, a very considerable amount. It would be desirable from an "operator comfort" viewpoint if one or more meter readings and the calculations could be eliminated. The test technique to be described accomplishes just this. The operator only has to observe the V_{CE} meter and the I_C meter in setting the operating point. The measurement of the ratio is all done internally when the operator adjusts a potentiometer such that a null is obtained on a meter. The test set described has a maximum possible error of roughly 2 percent for most transistors.

Design Principles of High Accuracy h_{FE} Test Technique

To measure h_{FE}, it is necessary to know the ratio of I_C to I_B. The circuit shown in *Fig. 2* may be used to make this measurement.

A voltage, V_1, will be developed across R_1 due to the current I_B. Also, a voltage V_2 will be developed across R_2 due to the current I_C. Two obvious relationships are:

$$V_1 = I_B R_1$$

$$V_2 = I_C R_2$$

These may be solved to give the currents I_B and I_C:

$$I_B = \frac{V_1}{R_1} \qquad I_C = \frac{V_2}{R_2}$$

By definition:

$$h_{FE} = \frac{I_C}{I_B}$$

or, using the above relationships for the test circuit:

$$h_{FE} = \frac{V_2/R_2}{V_1/R_1} = \frac{V_2 R_1}{V_1 R_2}$$

Here we see that if resistors R_1 and R_2 were known, the value of h_{FE} could be determined by measuring V_1 and V_2 and inserting their values in the above equation. However, the errors incurred in the measure-

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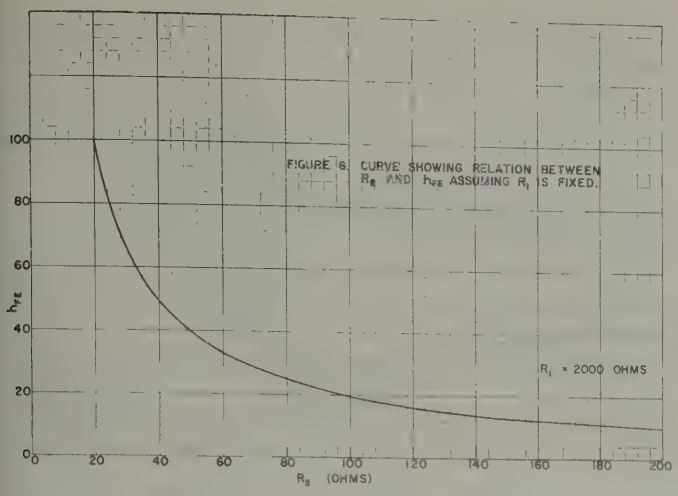

Fig. 3.—Curve showing relation between R_2 and h_{FE} assuming R_1 is fixed.

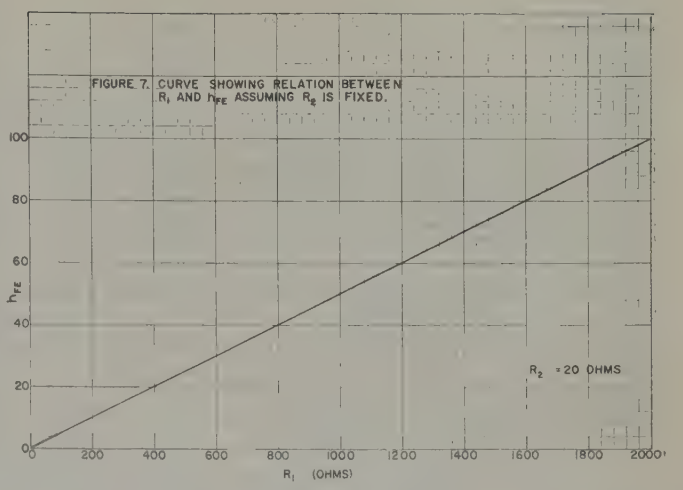

Fig. 4—Curve showing relation between R_1 and h_{FE} assuming R_2 is fixed.

ment of V_1 and V_2 would be as great if not greater than that obtained by using meters to measure I_C and I_B directly.

However, note that if V_1 and V_2 are of the polarities indicated in *Fig. 2*, V_3 will be the difference of the two voltages. Now assume that a very sensitive *d-c* null detector is used to measure V_3, and the ratio of R_1 to R_2 is adjusted by varying either resistor until the null detector indicates zero voltage for V_3. Now we know that since:

$$V_1 - V_2 = 0$$

Therefore $V_1 = V_2$

Thus, we have h_{FE} from a previous relationship:

$$h_{FE} = \frac{V_2 R_1}{V_1 R_2} = \frac{R_1}{R_2}$$

Resistors may be obtained with very highly accurate resistances. Thus, if the minimum voltage which will produce a reasonable deflection on the null detector is much less than the value of V_1 or V_2, the ratio of I_C to I_B may be obtained to a very high degree of accuracy.

It was previously mentioned that a null may be obtained either by varying R_1 or R_2 since only the ratio is important. However, if R_1 is fixed and R_2 is the variable, the value of h_{FE} is a non-linear function of R_2 as shown in *Fig. 3*.

On the other hand, if R_2 is fixed and R_1 is variable, then h_{FE} is a linear function of R_1 as shown in *Fig. 4*.

It is somewhat impractical to vary R_1 in the circuit since this requires that the base current generator have a very high impedance with respect to R_1. R_1 must have a value in the order of several thousand ohms in order to obtain sufficient voltages for V_1 and V_2 when small currents are involved. This would require an unreasonable base circuit generator in order that the base current, and indirectly the collector current, may remain constant when the null is being obtained. To allow I_B to vary, thus making readjustments necessary would require excessive work for the operator.

An easy way of eliminating this problem is the use of a modified circuit such as shown in *Fig. 5*.

Here, the actual value of R_1 to be used in the previous mathematical relationships is that value of the resistance of the potentiometer from "B" to "C". The null detector should have high input impedance for sharp nulls. Varying the slider on the potentiometer R_1 does not affect the value of I_B regardless of the output impedance of the base current generator.

It is difficult to obtain potentiometers with a sufficient degree of accuracy. Also, if high values of I_B are incurred in the measurement, a potentiometer of high power dissipation must be used. Such a potentiometer, if available, would be very expensive.

This problem may be eliminated by using a circuit such as shown in *Fig. 6*.

In this circuit, R''_1 is much less than the value of R'_1, the resistance of the potentiometer. R''_1, therefore, carries most of the current and dissipates a major portion of the power.

R'''_1 is that portion of the potentiometer, R'_1, which appears between terminals "B" and "C". The value of R_1 to be used in the mathematical relations given in the earlier discussion is:

$$R_1 = \frac{R'''_1}{R'_1}\left(\frac{R''_1 R'_1}{R''_1 + R'_1}\right)$$

This method has another advantage in addition to lowering the power dissipation requirements of the potentiometer. Since R''_1 is much less than R'_1, the accuracy of the parallel combination is primarily dependent on the value of R''_1. This allows the use of a lower precision potentiometer without loss in accuracy. Linearity of the potentiometer is still quite important, however.

The maximum value of h_{FE} that may be measured by the test circuit of *Fig. 6* is determined by the ratio of the parallel combination of R''_1 and R'_1 to R_2. The theoretical minimum is zero, although this point is never reached in practical cases.

Description of an h_{FE} Test Set Using the New Technique

Fig. 7 shows the block diagram of an h_{FE} test set designed to use the resistance null technique The base supply is capable of delivering 100 milliamperes maximum. It is made continuously variable from zero by the use of a variable autotransformer. Terminals are provided in order that the base current may be measured if it is desirable. A switch is provided to short out these terminals whenever an external I_B meter is not used. If desired, a finer adjustment of I_B may be obtained for low currents if a resistor is used in place of the meter. Vernier control may be obtained by making this resistor variable.

Since a voltage supply of roughly 180 volts maximum is used, a very

unpleasant electrical shock could be obtained if the operator were to touch the base terminal and ground. To prevent this hazard, a clamp consisting of a 0 to 5 volt power supply and two silicon junction rectifiers limits the voltage appearing at the front panel to a safe value.

Provision is also made to switch in an external base supply, if desired. Also, terminals are provided for the measurement of the base-to-emitter voltage, V_{BE}, whenever necessary.

The current "reading" resistors which correspond to resistors R'''_1 and R_2 are General Radio "500" series resistors. To obtain the higher power dissipation required, several parallel and series combinations were used. A range switch is provided to give three useful ranges: 0 to 10, 0 to 100, and 0 to 500.

The same base reading resistor is used in the two higher h_{FE} ranges, the range change being accomplished by changing the value of R_2 in the collector circuit. The base reading resistor is changed to give the low range scale and the value of R_2 is held the same as for the 0 to 100 range.

Separate "current" connections and "potential" connections are provided for each bank of resistors. This eliminates problems due to contact potential and contact resistance in the connections and switches. Also, this method eliminated some of the lead resistance problems that would otherwise be present. Extra heavy wire is used as indicated on the drawing in order to increase the accuracy by eliminating unwanted voltage drops.

In order to compensate for the presence of the potentiometer across the base resistor, an appropriate resistor must be placed across the collector resistor. This eliminates the necessity for non-standard values of resistance. These compensating resistors may be lower precision than for the main reading resistors. The ratio of the potentiometer resistance R'_1 to the compensating resistance must be the same as the ratio of the base reading resistor to the collector reading resistor.

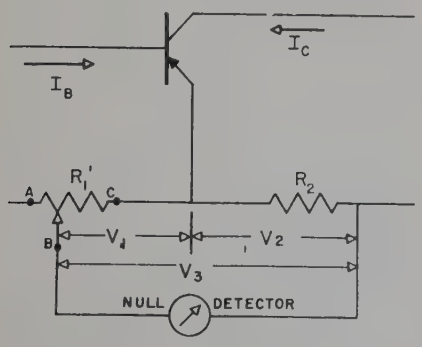

Fig. 5—Simple h_{FE} test circuit modified to eliminate problems in varying R_1 of test circuit shown in Fig. 2.

A *vtvm* circuit is incorporated in the test set to measure V_{CE}. If h_{FE} measurements were made only for high values of collector current, a simple microammeter type voltmeter could be used. However, for low values of collector current, a high impedance voltmeter is necessary.

The V_{CE} voltmeter must be connected directly between the collector and the emitter terminals, since the voltage drop across the meter and reading resistance may be equal to or even greater than the value of V_{CE}.

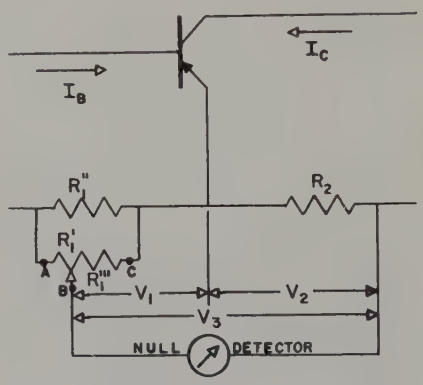

Fig. 6—Basic h_{FE} test circuit modified to allow high base current without loss in accuracy.

A multirange *d-c* milliammeter is provided for the measurement of I_C. If greater accuracy is desired, an external lab standard meter may be used.

The collector power supply consists of a 12-volt battery eliminator whose *a-c* input voltage is obtained from the variable output autotransformer. To aid in adjusting the voltage output a loading resistor is placed across the output terminals of the battery eliminator. Without a fixed load of roughly 1 ampere, the collector adjustment would be very sluggish due to the large filter capacitors in the battery eliminator.

One undesirable feature of the test set is the rather large voltage drop across the collector reading resistor for high collector currents. This voltage drop creates a slight problem whenever setting up the operating point for a transistor since varying the collector current slightly will also vary the collector voltage. To set up the operating point for a transistor requires adjusting first

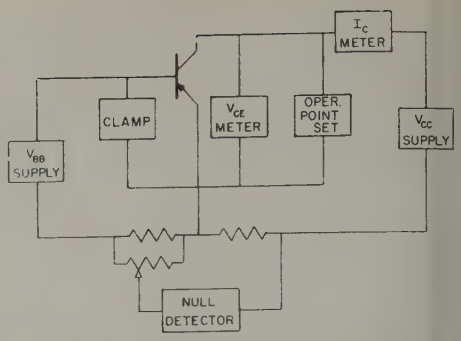

Fig. 7—Block diagram of a complete h_{FE} test set using the resistance null technique.

the collector voltage and then the base current (to set the collector current) several times in repetition.

Actually, for high collector currents, the value of this reading resistor could be made much lower. However, in a test set designed to measure h_{FE} for low currents as well as for high currents, the value of the reading resistance specified is necessary.

This problem of operating point set-up may be eliminated by the use of a fixed precision resistor in place of the transistor during the set-up procedure. Since the collector current, I_C and the collector voltage, V_{CE}, are specified for the operating point, the transistor appears as a fixed resistance of V_{CE}/I_C ohms. If a fixed resistor of this value is connected between the collector and emitter terminals of the test set (with no transistor in the circuit), and the collector voltage control advanced until the V_{CE} meter reads the required voltage, the I_C meter will read the required collector current. The fixed resistor is now removed. Now any time that the collector current, for which the operating point was set, is caused to flow, the collector voltage will be automatically set. A selector switch with 21 resistors required for the common operating points is provided.

The null detector used in conjunction with this test set was of a transistorized chopper type. Details are not given here but will be described in a future paper.

Conclusion

A novel technique for the measurement of h_{FE} has been described. The technique has other possible uses in transistor instrumentation.

ACKNOWLEDGEMENT

The author wishes to acknowledge the assistance of N. R. Richards, who did the parts layout and the construction for the test set. The suggestions made by my fellow engineers in the Transistor Engineering Section were also very helpful.

An Empirical Study of the Degradation of Alloy Transistor Characteristics With Operating Temperature

BERNARD REICH*

As a result of storage life tests concluded on two germanium alloy transistors and one silicon type, an empirical expression for the forward current transfer ratio, h_{FE}, is developed as a function of operating time and temperature. While it appears that surface effects dominate the degradation of transistor parameters during their operation, evidence is presented which indicates the possibility of impurity diffusion even at low operating temperatures.

ONE OF THE important questions often raised by designers considering the use of transistors is the matter of operating life. When they delve more and more into the subject, they will further ask about the life of transistors at different operating temperatures. The matter of transistor life is a broad area since its meaning to operating engineers differs. In most instances, the end of life characteristics of transistors is quite arbitrarily defined in terms of the specifications set forth by device consumers or by the manufacturer. Numerous requests were received from equipment groups throughout our laboratories and, as a result, a study was made of the life characteristics of two *p-n-p* germanium alloy transistors and one silicon type.

Experimental Procedure

The experimental procedure followed was to place sets of transistors in storage temperatures of 25° C, 55°C, 85°C, and 100°C. The purpose of storing units at the above temperatures was to determine whether device parameter degradation as a function of temperature could be determined. Two of the transistor types examined were *p-n-p* alloy germanium power transistors, each device type being subjected to an entirely different encapsulation environment by the individual manufacturer. Both types chosen were being produced in pilot line or in semi-production quantities. The silicon transistor will not be identified to any great extent, since the manufacturer of this device might be deduced from any identity provided. Ten units of each type were stored at the various temperatures indicated above for approximately 4000 hours. Measurements of device parameters, collector cut-off current I_{co}, and forward current transfer ratio, h_{FE}, were made at specified periods. The measurements were made 30 to 60 minutes following removal from the storage chambers. In this report, the data recorded will be presented, and an analysis made on the variation of current gain as a function of operating temperature and storage time.

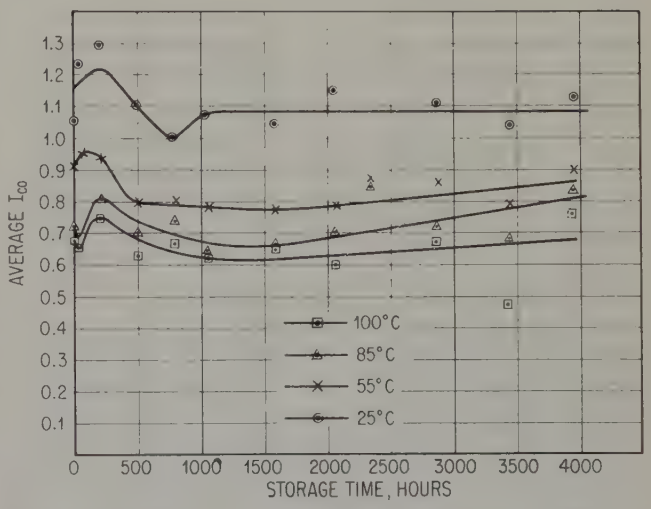

Fig. 1—Average I_{co} (in *ma*) *vs* storage time; *p-n-p* Type A.

Results On *P-N-P* Alloy Transistor (Type A)

Type A, power transistor, has a maximum junction temperature of 85°C, although in the experimental procedure outlined above the units were subjected to temperatures up to 100°C. *Fig. 1* is a plot of the variation of I_{co} as a function of time at various storage temperatures. The values plotted represent the average of ten units. The following comments seem applicable to the data plotted in *Fig. 1*. The units stored at the elevated temperatures seem to stabilize at times approximating 500-2000 hours depending on the storage temperature. Beyond this time, they appear to follow a predictable rate of increase. The data does not clearly indicate any I_{co} rate increase with temperature following stabilization.

Figure 2 is a plot of the variation of *d-c* large-signal current transfer ratio measured at 0.5 ampere as a

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function of time and temperature. At 25°C, no appreciable change in gain is noted. Above 25°C, increased changes in current gain are noted, the initial degradation being a function of storage temperature. For the purposes of analysis, it is assumed that the current gain at any time can be expressed as follows:

$$h_{FE} = h_{FE_1} + (h_{FE_0} - h_{FE_1})\, e^{-kt} \qquad (1)$$

where h_{FE} is the forward current transfer ratio at any time.

h_{FE1} is the stabilized value of gain and corresponding to the asymptotic value of the transfer ratio curves.

h_{FE0} is the forward transfer ratio at time $t = 0$.

k is the degradation constant per hour, and

t is the time in hours.

It appears from *Fig. 2* that the stabilization time of current gain is dependent on the storage temperature. Increasing the storage temperature decreases the stabilization period. Beyond this stabilization period which, at 55°C appears to be approximately 2000 hours (h_{FE1}), the gain variation with time is small and not visibly evident in the curves. Assuming that Equation (1) is representative of the current gain expression with life, the values of k, the degradation coefficient, are shown in Table I. These values were calculated from the curves presented in *Fig. 2*.

Results On *P-N-P* Alloy Transistor (Type B)

Type B power transistor had an encapsulation environment which differed radically from that seen by the Type A unit. *Fig. 3* is a plot of I_{co} as a function of time for this unit. At temperatures 25°C and 55°C, no perceptible activity is noted in the I_{co} parameter as a function of time. At 85°C, the I_{co} has a positive slope of approximately 1.3 *ma* per 1000 hours while the 100°C curve increases approximately 3.7 *ma* per 1000 hours. These curves seem quite different from those presented in *Fig. 1*.

Figure 4 is a plot of the forward current transfer ratio as a function of time and temperature of the Type B units. These measurements were made at 0.5 ampere, the same measuring point used on the Type A units. At 25°C, some variation in the *d-c* current gain is noted, being attributed to heating of the transistor during measurement of I_{co}. Examination of the curves of units stored at 55°C, 85°C, and 100°C yield a similar picture as with the Type A units, although the stabilization times at these temperatures are not quite as long. Assuming current gain degradation as defined by Equation (1), Table II gives the degradation factor k, for the Type B units.

Results On The Silicon Type

The silicon transistor under study was subjected to the same environmental conditions as the two germanium types previously discussed. *Fig. 5* is a plot of I_{co} as a function of time and operating temperature.

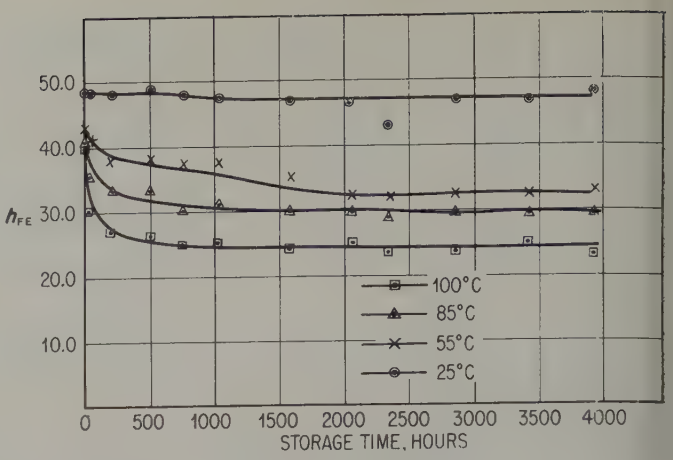

Fig. 2—Average h_{FE} vs storage time; *p-n-p* Type A.

Instability is evident up to 2000 hours for the units stored at 100°C. Stabilization occurs at the lower storage temperatures in a shorter time interval.

Figure 6 is the accompanying plot of *d-c* forward current transfer ratio on the units. With the germanium units, a more uniform degradation pattern was noted; however, *Fig. 6*, for at least 1500 hours, exhibits many "wiggles." The degradation coefficient, k, was obtained from Equation (1) and the data presented in *Fig. 6*. Table III is a summary of the information thus calculated.

Beyond the 1500 hour stabilization time, the forward current transfer ratio at 55°C, 85°C, and 100°C seems to be decreasing at the rate of approximately 0.3 per 1000 hours. This readable drop on the silicon units may be due to the low level magnitude of the transfer ratio being examined. Small changes are easily perceptible on the silicon units, while the magnitude of the transfer ratio on the germanium units

TABLE I

Degradation Coefficient as a Function of Temperature Type A Transistor

Degradation Coefficient (Per Hour)	Temperature °C
$k_1 = 1.1 \times 10^{-3}$	55
$k_2 = 6.7 \times 10^{-3}$	85
$k_3 = 13.3 \times 10^{-3}$	100

TABLE II

Degradation Coefficient as a Function of Temperature Type B Transistor

Degradation Coefficient (Per Hour)	Temperature °C
$k_1 = 1.3 \times 10^{-3}$	55
$k_2 = 6 \times 10^{-3}$	85
$k_3 = 20 \times 10^{-3}$	100

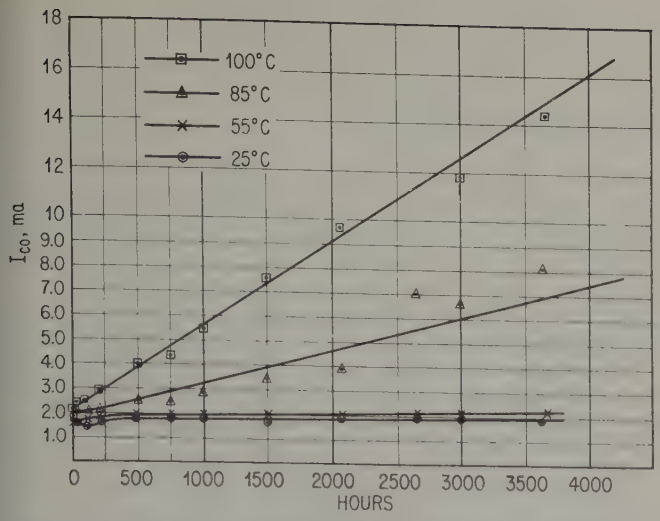

Fig. 3—Average I_{co} *vs* storage time; *p-n-p* Type B.

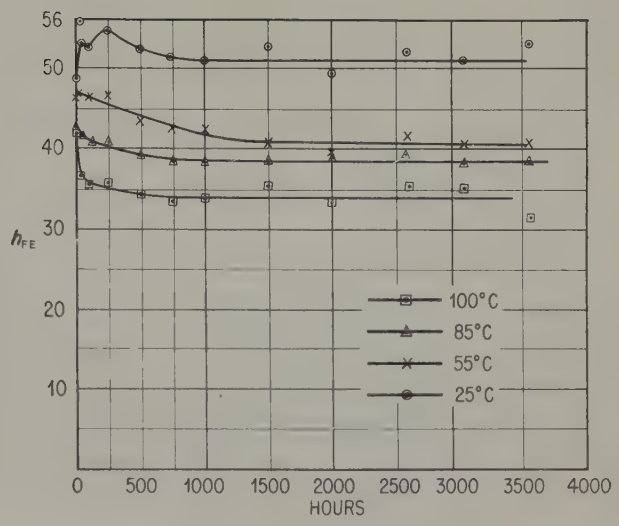

Fig. 4—Average h_{FE} *vs* storage time; *p-n-p* Type B.

does not allow for the perception of small changes over the measurement interval.

Analysis of Results

The data presented in *Figs. 1-6* indicate that, in general, the forward current transfer ratio, h_{FE}, and collector cut-off current, I_{co}, stabilize after many hours (up to 2000) of storage. The collector cut-off current does not seem to lend itself to any sort of analytical solution for the following reason. The curves presented indicate this parameter variation of the 60 volt value on the two germanium units examined; therefore, the value of change in leakage current may merge with surface breakdown conditions tending to cloud any possible analysis.

The forward current transfer ratio variations with time and temperature seem to lend themselves to analysis. Equation (1) represents the current gain expression as a function of time at a particular tem-

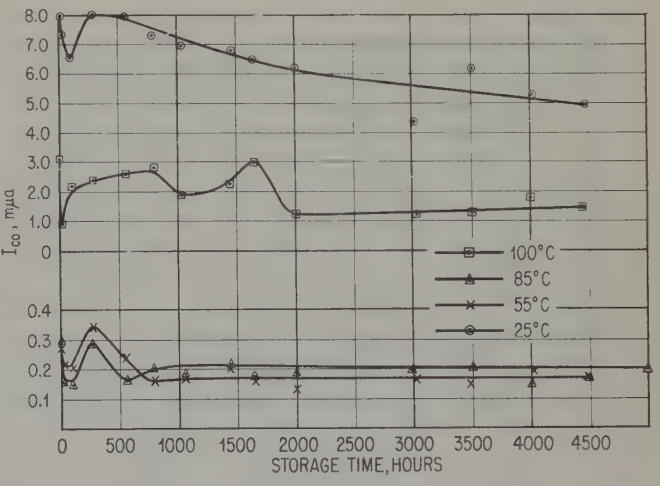

Fig. 5—Average I_{co} *vs* storage time; silicon type.

TABLE III

Degradation Coefficient as a Function of Temperature (Silicon Transistor)

Degradation Coefficient (Per Hour)	Temperature °C
k_1 — Not calculable	55
$k_2 = 1.1 \times 10^{-3}$	85
$k_3 = 2.7 \times 10^{-3}$	100

TABLE IV

Values of Rate Constant and Energy

Transistor Type	D (Per Hour)	E (Volts)
A	2.0×10^6	0.61
B	1.6×10^5	0.53
Silicon	4.4×10^6	0.69

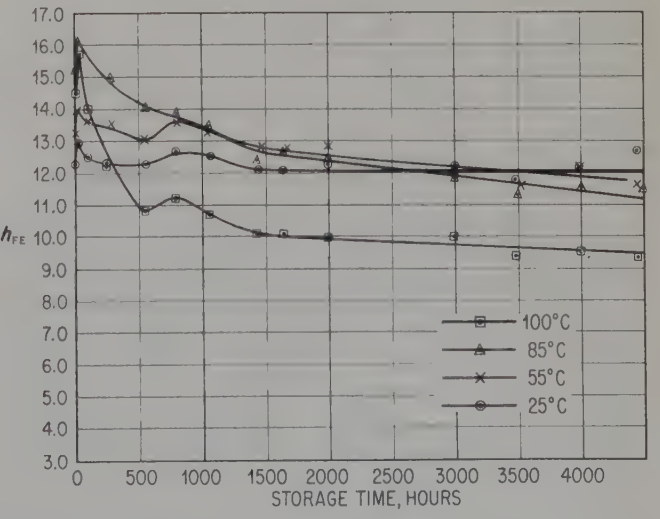

Fig. 6—Average h_{FE} *vs* storage time; silicon type.

perature. In Tables I, II, and III, values of k, the degradation coefficient, are given for the two germanium types and for the silicon unit. By suitable graphical anaylsis, it is found that k is an exponential function of temperature. It is assumed that k can be expressed as follows:

$$k = De^{-\frac{qE}{KT}} \qquad (2)$$

where D is a rate constant (per hour),

q is the charge on the electron,

K is Boltzmann's constant,

E is an energy associated with the degradation process.

T is the absolute temperature.

From the data presented in Tables I-III, values of D and E can be calculated. Table IV tabulates the values of D and E for the three transistor types examined.

It is noted from Table IV that the value of E seems to be in the range of 0.53-0.69 volts. Considering the fact that the data was taken from the curves *Figs. 1-6*, these values are remarkably close. It is interesting to note that the value of E for the silicon transistor is close to those values obtained on the germanium devices. This means that the rate of change of degradation coefficient, k, in Equation (1) with temperature is approximately the same.

From the information presented, and utilizing equations (1) and (2), it appears that the forward current transfer ratio can be expressed completely as

$$h_{FE} = h_{FE1} + (h_{FE0} - h_{FE1})\, e^{-De^{\frac{-qE}{KT}}} \qquad (3)$$

where the above terms have previously been defined.

From the preceding data presented, it could readily be assumed that the degradation of parameters is solely due to surface change with time and temperature. Before a final conclusion is reached based on this assumption, however, the author presents some data which may lead to further deliberation on the problem.

Prior to these extended life tests, some work was done on analyzing the variation of forward current transfer ratio as a function of temperature at a level where emitter efficiency limited this parameter.[1] It was found that in germanium transistors where high conductivity emitters were readily obtained, the temperature-transfer ratio variation at high injection levels was due primarily to the magnitude of base resistivity, ρ_b. Adjusting ρ_b would vary the transfer ratio temperature characteristic of a device.

1) Temperature Sensitivity of Current Gain in Power Transistors, Transactions of the IRE-PGED, July 1958

Some study was made of the transfer ratio temperature curve as a function of storage time at elevated temperatures (85°C-100°C). It was found that most transistors would exhibit the tendency to show reduced gain as a function of storage time. The original curve at zero time and succeeding curves at different time intervals would all be parallel to each other. Assuming the analysis referred to previously[1] to be true, then the changes noted would be attributed entirely to the surface.

Some of the transistors examined, however, exhibited not only a change in the magnitude of the transfer ratio as a function of temperature, but also a displacement of the peak of the transfer ratio temperature curve. This shift in the curve was in a direction such that the virtual base resistivity close to the emitter was decreased. Upon noting these changes, some of the units were returned to the manufacturer for further etching, and the curves were re-run. After etching, it was noted that the magnitude of the transfer ratio *increased*, but the displacement in the curve remained *unchanged*.

With the additional evidence presented, it is not as readily concluded that the changes noted in the transfer ratio as a function of storage life can be solely attributed to surface changes, but also, possibly, to impurity diffusion into the semiconductor. The empirical equation (2) developed would also apply to the diffusion process. It is realized that diffusion at these temperatures is small, but the times involved for complete stabilization may run 500 hours at 100°C.

Conclusions

Based on storage life test data gathered on two germanium alloy transistors and one silicon type, an approximate empirical expression for the forward current transfer ratio, h_{FE}, at any time and temperature during the storage life of the device has been developed. The mechanisms of the transfer ratio degradation as a function of time is not clearly understood; however, data is presented on the possibility of change of virtual resistivity of the base region, the portion affecting the transfer ratio. The study, at present, is not complete in that only the alloy junction transistor has been examined. Other types of structures have to be studied, and these studies have already commenced. In addition, the units studied in this report will be continually observed to see if recovery of the characteristics takes place upon removal from the storage environment.

Acknowledgment

Acknowledgment is made of the efforts of Messrs. T. Redgate and S. Stern of these Laboratories in gathering the data presented in this report. Acknowledgment is also made of the valuable discussions held with Dr. H. Jacobs, Dr. W. W. Gärtner, and Lt. R. Anderson, also of these Laboratories.

Processing and Purification of Silicon for Semiconductor Use

DAVID K. HARTMAN*

Silicon as a semiconductor material is rapidly receiving wide acceptance. It appears to be the one elemental material that will dominate the semiconductor business in the future. Silicon for semiconductor usage is derived by the reduction of silica or quartz. This impure silicon is converted to silicon tetrachloride, silicon tetraiodide, silane or other similar silicon compounds for further chemical purification. Hyper-pure silicon is commercially available today, only by the zinc reduction of silicon tetrachloride. Other processes are being evaluated, one of which is the reduction of silicon tetraiodide. In order to use the hyper-pure zinc reduced silicon, the General Electric Company is currently densifying, zone refining and then doping it to desired impurity levels. Zonal purification has proved desirable in silicon purification work in order to homogenize the silicon, to facilitate controlled doping for specific devices to improve the quality of the bulk material by elimination of deleterious elements, and finally, to reclaim scrap silicon for further processing and use in the semiconductor device areas.

INTRODUCTION

SOLID MATTER can generally be classified as either a metal, insulator, or a semiconductor. The history and knowledge of metals and insulators dates back to antiquity whereas the first significant observation in the semiconductor field only dates back to 1833 when Michael Faraday found that silver sulphide had a negative temperature coefficient of resistance. By 1904 several fundamental properties of semiconductors had been discovered including (1) negative temperature coefficient of resistance, (2) photoconductivity, (3) photoelectromotive force, and (4) rectification; and it was in this period that semiconductors such as galena, iron pyrite, and silicon were finding application as detectors in the radio field. With the discovery and acceptance of the vacuum tube, however, semiconductor interest lagged until the late 1930's and the World War II years when silicon detectors became of importance in radar systems, and selenium and copper oxide became important as rectifying elements. Since the discovery of the transistor in 1948, there has been a most remarkable growth of the semiconductor field, both technically and from a commercial point of view.

The elemental semiconductors are found in column IV of the periodic chart and are identified as grey tin, germanium, silicon, and carbon in the form of diamond. Grey tin exhibits semiconducting properties only at temperatures below 0°C and so has attracted little commercial interest. On the other hand, both germanium and silicon have been, and are being widely exploited for semiconductor devices. Germanium although considered a rare element, has dominated the semiconductor market until the present time because of the ease of chemical purification and handling. However, germanium is scarce and it also has the temperature limitations since it fails to exhibit semiconducting properties much above 100°C. Of the elemental semiconductors, silicon appears to have the brightest future and will undoubtedly supersede germanium in many device areas. This is true because of its abundance in nature and also because silicon devices exhibit favorable semiconducting characteristics above 200°C. The semiconducting properties of carbon in the form of diamonds are being studied in research laboratories today, but have attracted no attention from device manufacturers. It thus becomes the purpose of this article to examine silicon and to discuss, in particular, its processing and purification.

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Chemistry of Semiconductor Grade Silicon

Silicon is the most abundant solid element on the surface of the earth. Because of its great chemical activity, it is never found free in nature. The simplest natural state for silicon is that in which it is combined with oxygen in the form of quartz or silica, that is SiO_2. It is this form that is selected by the chemist in order to prepare elemental silicon.

People interested in purifying silicon for semiconductor purposes start with a low-purity material reduced directly from SiO_2. If an excess of silica reacts with carbon at extreme temperatures in an inert atmosphere, the resultant products are carbon monoxide and silicon. This relation is:

$$SiO_2 + 2C = 2CO + Si.$$

The elemental silicon derived from this process has carried with it such impurities as iron, copper, aluminum, manganese and other elements that are deleterious to semiconductor devices. Two processes for producing semiconductor grade silicon are the zinc

TABLE I

DISTRIBUTION COEFFICIENTS OF SELECTED ELEMENTS IN SILICON

Element	Weight	Distribution Coefficient of element in silicon	Method	Reference
Boron B	10.82	0.68 0.9	C C	(1) (2)
Aluminum Al	26.98	0.0016 > 0.004	C C	(1) (2)
Gallium Ga	69.72	0.004 0.01	C R, C	(3) (2)
Indium In	114.76	0.0003 0.0005	C R, C	(1) (2)
Phosphorous P	30.98	0.5 0.35	C R, C	(4) (2)
Arsenic As	74.91	(0.07)* 0.3	C R, C	(1) (2)
Antimony Sb	121.76	0.018 0.04	C R, C	(1) (2)
Tin Sn	118.7	0.02	R	(2)
Copper Cu	63.54	4×10^{-4}	R	(2)
Gold Au	197.2	3×10^{-5}	R, C	(2)
Tantalum Ta	180.88	10^{-7}	R	(2)

* There is reason to believe that this value is in error, and that Burton's figure is more nearly correct.

Method C -- Conductivity measurement of donor or acceptor concentration.
R -- Radioactive tracer measurement of impurity atom concentration.

(1) R.N. Hall, J. Phys. Chem., 57, 836, (1953)
(2) J.A. Burton, Physica, XX, 846, (1954)
(3) Private communication from C.B. Collins and D.M. Hinz
(4) Private communication from R.O. Carlson and C.B. Collins

Data based on Hall and conductivity measurements.

reduction of silicon tetrachloride and the decomposition on quartz of silicon tetraiodide. Silicon tetrachloride can be derived by the direct reaction of chlorine with silicon or the reaction of carbon and chlorine with silica. For the latter condition, high temperatures are required. These two chemical reactions are as follows:

$$Si + 2Cl_2 = SiCl_4$$

or

$$SiO_2 + 2C + 2Cl_2 = SiCl_4 + 2CO.$$

Silicon tetrachloride when reacted with zinc at a temperature above the boiling point of zinc chloride yields, on proper processing, a high purity silicon that has been used for silicon detectors, rectifiers, and transistors. This reaction is given by:

$$SiCl_4 + 2Zn = 2ZnCl_2 + Si.$$

An early version of a reactor chamber used for preparing high purity silicon by the zinc reduction process is shown in *Fig. 1.*

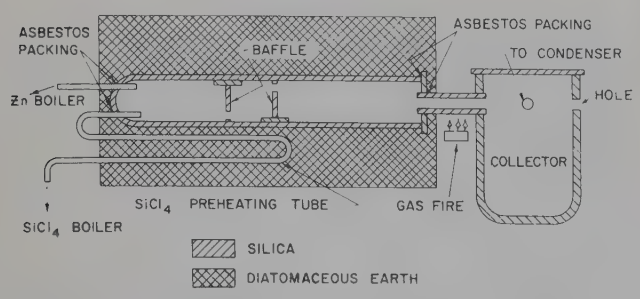


Fig. 1—A cross sectional view of an early version of a reactor chamber for preparing high purity silicon by the zinc reduction of $SiCl_4$. Reference: Torrey and Whitmer, "Crystal Rectifiers," McGraw-Hill, Page 302, New York, 1948.

To date, there is only one process which has been commercially successful for chemically purifying silicon to semiconductor grade. This is the zinc reduction of silicon tetrachloride which is used by duPont and Sylvania, suppliers of silicon for semiconductor use. There are many other processes being evaluated including the reduction of silicon tetrabromide ($Si Br_4$), silance (SiH_4), tri-chloro-silane ($SiHCl_3$) and silicon tetraiodide ($Si I_4$).

The General Electric Company has devoted considerable effort to the silicon tetraiodide process. Here silicon is reacted with iodine to convert the silicon to the tetraiodide form.

$$Si + 2I_2 = SiI_4.$$

The silicon tetraiodide is then allowed to recrystallize several times in a normal heptane solvent. The silicon tetraiodide derived by recrystallization is then fractionally distilled in a large distillation column. Finally, it is decomposed at approximately 900°C on a hot quartz tube. The steps used in the process are shown in *Fig. 2.* It is of interest to note that the purification process reduces a 99.7% pure material to one having a purity greater than 99.999999%. This represents an impurity content of less than one part per 100 million.

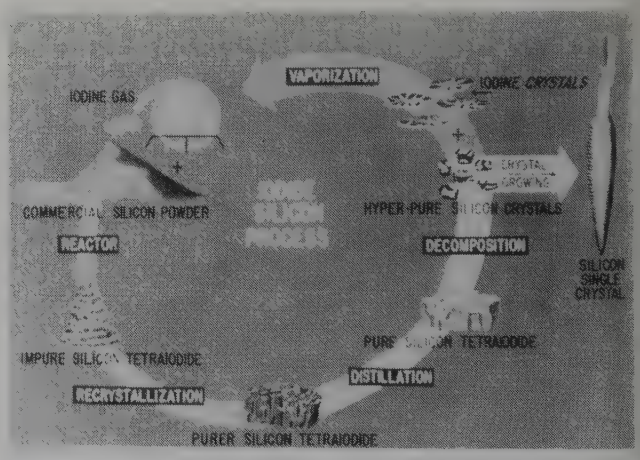


Fig. 2—The process used by the General Electric Company in the purification of silicon by the silicon tetraiodide process.

The Densification and Zone Refining of Semiconductor Grade Silicon

In spite of the high degree of purity after chemical purification, the silicon has not been consistently adequate for controlled semiconductor usage. It has been found advantageous to control the impurities to even a higher degree and to eliminate such impurities as

iron, nickel, copper and manganese to less than 1 part in 10 billion.

Had the purification of silicon not progressed over the past several years, its use would still be limited to a narrow scope of semiconductor devices, such as detectors. However, in order to arrive at a purer, more uniform product, the General Electric Company has chosen to process the hyperpure silicon obtained from duPont through a densification process and through the additional purification of zone refining. *Fig. 3* shows a picture of forms of silicon commercially available. One form is a needlelike silicon derived directly from the decomposition chamber and the other is a densified material derived by melting the needle material in a large pot and then permitting it to freeze.

Starting with the needle silicon, a thin walled quartz test-tube approximately one inch in diameter and 15 to 18 inches long is used to cast what we call a pre-melt ingot. This is obtained by melting a small kernel of silicon in the bottom of the test tube and then adding needle silicon to this melt. In a short period one is able to cast a poly-crystalline ingot of approximately 15 to 18 inches in length. The quartz tubing is removed from the ingot by dissolving in hydrofluoric acid, and it is this ingot that is then zone

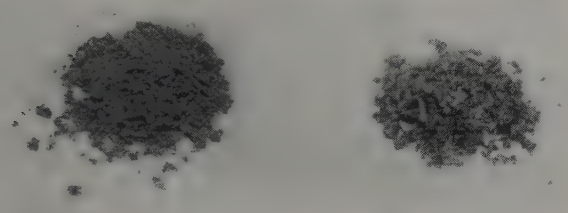


Fig. 3—Two forms of silicon available from E. I. DuPont Company—a needle and a densified form of silicon.

purified. *Fig. 4* depicts the equipment used for premelting the silicon. Typical premelt bars are shown in *Fig. 5*.

Zone purification is a powerful method of purifying materials to a greater degree. It is universally used with germanium and we, in General Electric, believe it has proved its value in silicon purification. Zone melting was first described by W. G. Pfann of Bell Laboratories and was first used in removing impurities from germanium. It was then successfully applied to purifying silicon by F. H. Horn and E. A. Taft of the General Electric Company. Now zone refining of silicon has been engineered to the point where it is performed on a routine basis. All impurities having a distribution coefficient much less than one are rejected to the tail end of the bar whereas all impurities having a distribution coefficient greater than one are rejected to the front end of the bar. Those impurities having a distribution coefficient close to one are not appreciably affected by zone purification. Table I lists pertinent data on the distribution coefficients of im-

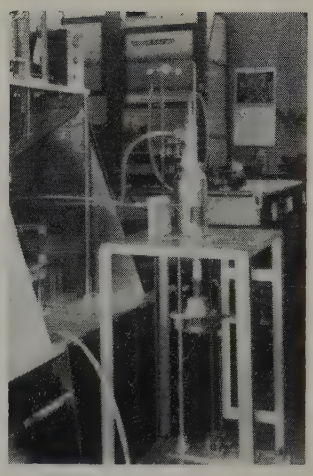


Fig. 4—The equipment used for densifying or premelting the needle form of silicon.

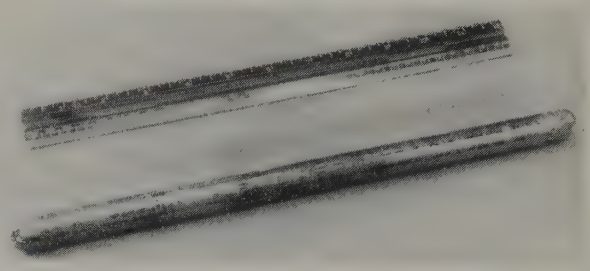


Fig. 5—The test tube for casting the premelt ingot and a completed premelt bar that has been cleaned prior to zonal purification.

purities found in the processing of silicon. Note, that with the exception of boron, all impurities listed have a distribution coefficient in silicon considerably less than one. These impurities thus zone purify satisfactorily. Since boron has a distribution coefficient approaching unity it is difficult to reduce its level through zonal purification.

In order to better understand the purification processes used in semiconductor work a sequence of animated pictures are presented showing how normal freezing, zone leveling and zone refining behave. In normal freezing, one starts with a completely homogeneous liquid and then this is permitted to cool directionally from one end of a boat. As the liquid freezes, impurities are rejected from the solid to the liquid phase with the result that the initial material has been purified while the tail end has had its impurity concentration increased. In zone leveling, a small molten zone is established at the front of an ingot. Impurities may be purposely introduced into this zone. Then as the zone moves through the bar, a condition is reached where the number of impurities entering the narrow molten zone are balanced by the number of impurities solidifying out of this zone. This technique permits the generation of a homogeneous material except at the front and back ends of the ingot. Next zonal purification is depicted where successive narrow molten zones are passed through an ingot. In this process, it is noted that each successive zone removes impurities from the front and carries the im-

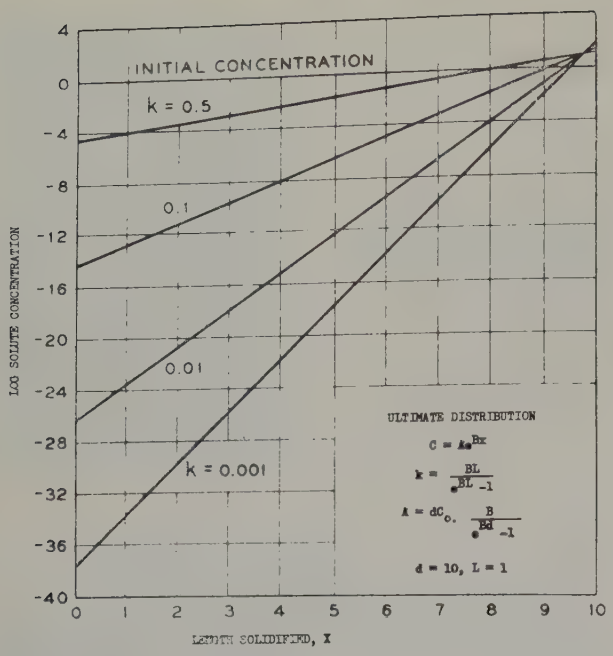


Fig 6—Curves showing the ultimate solute concentration after multiple zone refining.

These curves are extracted from W. G. Pfann's article, "Principles of Zone Melting," July 1952, Journal of Metals, Page 751.
Courtesy: American Institute of Mining, Metallurgical and Petroleum Engineers.

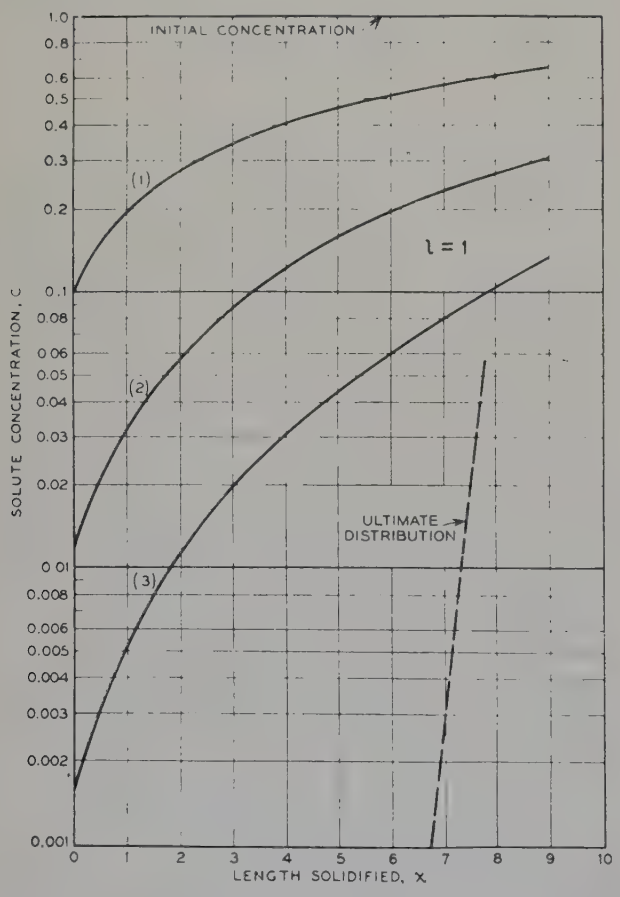


Fig. 7—Concentration curves showing solute concentration in a solid as a function of the length solidified for an impurity having a distribution coefficient of K = 0.1 after 1, 2, and 3 successive single zone passes.

These curves are extracted from W. G. Pfann's article, "Principles of Zone Melting," July 1952, Journal of Metals, Page 751.
Courtesy: American Institute of Mining, Metallurgical and Petroleum Engineers.

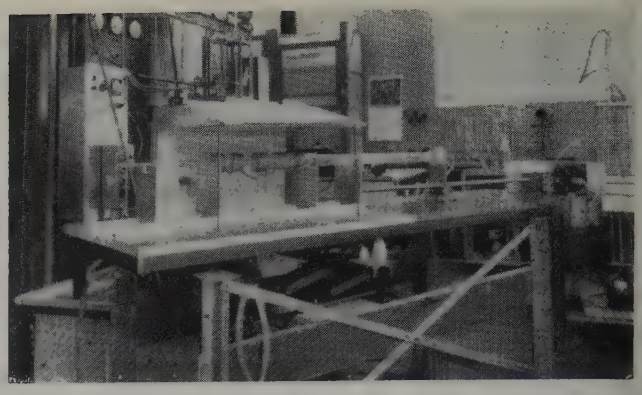
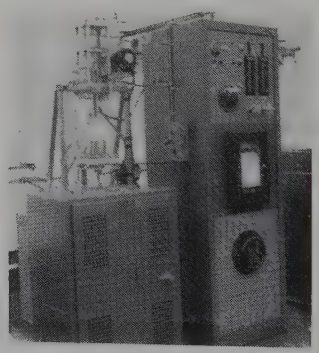


Fig. 8—The equipment used for zonally purifying silicon.

purities to the back end of the ingot. Without the intentional addition of impurities such as in the zone leveling process, this technique succeeds in purifying materials such as metals and semiconductors.

Referring to *Fig. 6* and 7 which were derived by Pfann, we see graphically how impurities are eliminated as a function of the number of zones used in zonal purification and also as a function of the distribution coefficients. *Fig. 6* in particular shows how the ultimate distribution of impurities behaves as a function of the distribution coefficient. Neglecting the back diffusion of impurities, it is noted that the impurity concentration for impurities having a $K \leqslant 0.001$ are for all practical purposes eliminated from the front end of the ingot. *Fig. 7* considers an impurity having a distribution coefficient of $k = 0.1$ and shows how the impurity concentration behaves as a function of 1, 2, and 3 passes and then compares this with the ultimate concentration after an infinite number of passes. It is thus apparent that zonal purification is a powerful tool for cleaning semiconductor materials.

The equipment used at the General Electric Company for zone purifying of silicon is shown in *Fig. 8*. Five zones and one pass are used on this particular zone refiner. The material is moved through an RF field at a rate of 6 to 7 inches per hour. The results are shown in *Fig. 9*. Here we see a typical zone billet that has been processed in a thin walled quartz boat approximately 15 to 18 inches long.



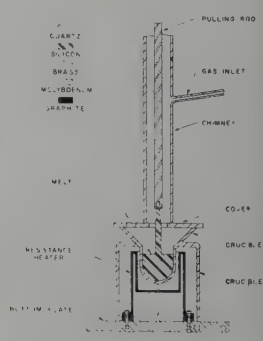


Fig. 10—(Left) Resistance heated single crystal silicon furnace.

Fig. 11—(Right) A cross-sectional view of the silicon pulling furnace

Fig. 9—A typical zone billet with a thin walled quartz boat used during zoning.

After the purification, the quartz boat is removed from the silicon by dissolving in hydrofluoric acid. This silicon is then processed directly into single crystals. These crystals are generated by the conventional Czochralski technique. The single crystal furnace is shown in *Figs. 10* and *11*. The source of heat for this furnace is a resistance heater. Typical single crystals grown in this furnace are shown in *Fig. 12*.

Advantages of Zonal Purification of Silicon

The resistivity of a semiconductor is a measure of the impurity content of the material. Lifetime is a measure of the rate at which charge carriers recombine and is indicative of the crystal perfection and also gives some indication of the level of iron, copper, and other harmful elements in the semiconductor material.

In 1952 it was difficult to obtain any material having a resistivity greater than 30 to 40 ohm-cm, which indicates a total impurity content of approximately one impurity atom for every 10^7 silicon atoms. Today, in the better lots of silicon, we see less than one impurity atom for every 5×10^8 silicon atoms. However, to manufacture reliable silicon semiconductor devices, one needs a very careful control of the number of impurity atoms. We have found that lots of silicon have fluctuated considerably in quality. Zonal purification has been extremely valuable for homogenizing these lots. We thus have a great deal of reproducibility from lot to lot of our material after zonal purification.

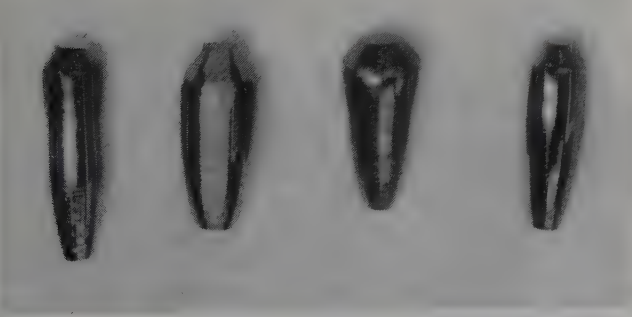


Fig. 12—Typical single crystals of silicon grown from the single crystal silicon furnace.

This permits and facilitates controlled doping of silicon to lower resistivity levels for specific device applications.

Unlike germanium, silicon sludge and croppings from single crystal silicon have been of little interest. It has been shown, however, that scrap silicon which is derived from reject billets or from the tail-ends of crystals can be reclaimed by zonal purification and can be used for certain semiconductor devices.

Finally, zonal purification has been a means available for purifying silicon so that bulk material will exhibit appreciable lifetime. Silicon that has been zone refined and then processed into a single crystal by the Czochralski method has yielded lifetimes well in excess of one millisecond as compared with less than 100 microseconds for crystals from material that was not zone refined.

TABLE II

EVALUATION DATA TAKEN ON SINGLE CRYSTALS OF SILICON GROWN FROM DuPONT MATERIAL AT VARIOUS STAGES OF PROCESSING

Lot No.	Stage of Processing	Resistivity Readings in ohm-cm			Lifetime Readings in usec.			Remarks
		10%	40%	80%	10%	40%	80%	
A	Needle	560	420	660	-	-	-	P-type, material compensated, barriers, photosensitive.
	Densified	95	28	11	-	-	-	N-type, compensation, barriers
	Premelt	79	71	53	300	190	90	P-type, slight compensation
	Zone Refined	112	67	22	60	47	35	P-type, normal boron segregation
B	Needle	260	553	75	-	-		P & N junctions, material compensated, barriers
	Densified	900+	44	19	-	-	-	P & N junctions, crystal cored, material compensated
	Premelt	188	465	49	-	-	-	P-type, material cored, photosensitive, compensated
	Zone Refined	110	93	29	40	30	20	P-type, nearly normal boron segregation

Table II shows a tabulation of results obtained on two lots of duPont material at various stages of processing. In general, it can be concluded from this table that material after zonal purification and after processing into single crystal silicon is more homogeneous and shows a more normal segregation of impurities. The silicon is not only free of barriers and coring effects but is of sufficient uniformity that meaningful lifetime measurements can be made.

Table III shows evaluation data taken on successive sections of zone refined billets from assorted lots of duPont silicon. The conclusions that can be reached from these data are that in general the evidence for compensation of impurities increases as one approaches the tail end of the bar; it is possible to obtain lifetimes in silicon greater than 1 millisecond after zone refining the material; and it becomes apparent that the working level of impurities in each lot is approximately the same.

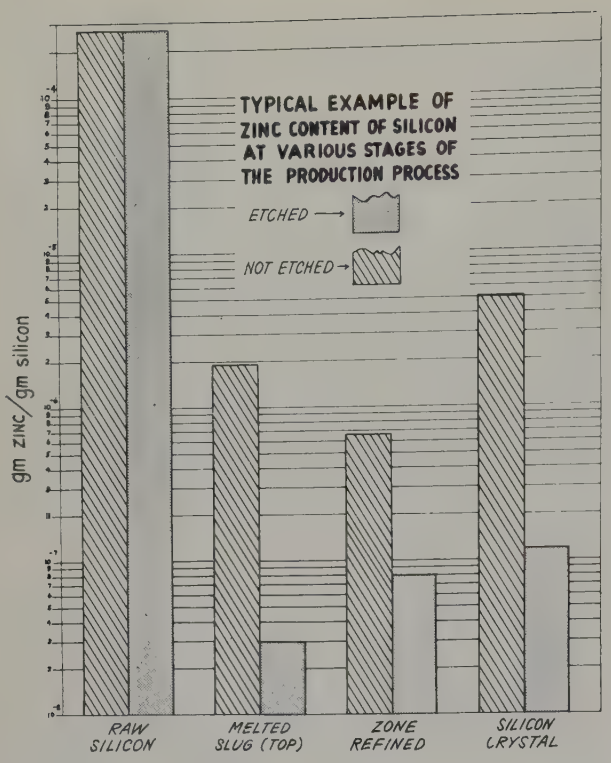


Fig. 13—Chart showing zinc content in silicon at various stages of the production process. This zinc content was representative of the early DuPont lots of silicon.

TABLE III

EVALUATION DATA TAKEN ON SINGLE CRYSTALS IN SILICON GROWN FROM SUCCESSIVE SECTIONS OF ZONE REFINED BILLETS

DuPont Lot No.	Zone Section	Resistivity Readings in ohm-cm 10%	40%	80%	Lifetime Readings in usec. 10%	40%	80%	Remarks
S-6114N	10% Sect.	180	105	42	-	-	-	P-type, photo-sensitive.
	60% Sect.	108	80	30	2000	800	300	P-type
S-6195N	10% Sect.	275	180	85	-	300	-	P-type
	40% Sect.	600	1100	1500	-	-	-	P-type, compensated & crystal cored.
	60% Sect.	300	900	125	-	50	-	P-type, heavily compensated
S-6205N	10% Sect.	225	240	205	200		100	P-type, slight compensation
	40% Sect.	140	95	45	1000		300	P-type
	60% Sect.	490	1450	55	-	-	-	P-type, compensated, crystal cored.
S-6337N	10% Sect.	165	130	98	-	-	-	P-type, crystal cored.
	40% Sect.	75	57	25	800	600	300	P-type
	60% Sect.	120	108	60		~600		P-type

ZONE REFINED INGOT, duPONT LOT #371-2

All Readings in ppb (10^{-9} gm/gm Si)

	Au	As	Cu	Sb	Fe	In	Bi	Co	Zn	Sc
Top	0.05	0.3	16.0	0.2	70	6.0	1.5	0.6	7.0	0.02
Bottom	0.4	4.0	7.8	1.0	300	17.0	6.0	1.0	7.0	0.03

	Zr	Ga*	Ag	Cd	Mo	Ca	Pt	Hg	Ni	Cr
Top	3.0	100	2.0	0.8	1.0	5000	0.9	3.0	200	100
Bottom	3.0	100	2.0	30.0	3.0	6000	2.0	10.0	200	100

	Sn	Mn	Al	Mg	V	B**	Pb**	Ta	Na
Top	20.0	0.5	100	80	500	5000	5000	3.0	0.04
Bottom	6.0	1.0	100	100	500	5000	5000	3.0	0.9

* Transportation delay - ARCO to Schenectady

** Spectrochemical analysis.

Table IV—An activation analysis study of a zone refined billet from DuPont lot No. 371-2. Impurities in ppb are measured at the front and at the tail end of the billet.

Figure 13 gives further evidence of the advantages of zone refining. Specifically the level of zinc was examined at various stages of processing silicon in the early phases of the work. The data obtained were generated by activation analysis. Again it becomes apparent from these data that there is an advantage to zone refining.

Table IV shows data collected by analyzing the front and tail end of a zone refined billet. These data measure the impurity content of assorted elements in parts per billion. Here it is to be noted that, in general, there is a higher concentration of impurity elements in the tail end of the zone billet than in the front end. These data were also derived through activation analysis and again emphasize the advantage of zonal purification in silicon.

SUMMARY

In summary, silicon today is available by zinc reduction of silicon tetrachloride. The reduction of silicon tetraiodide is being studied. The General Electric Company has found it desirable to use the needle form of silicon, densifying it, then purifying it zonally, and finally processing it into single crystals of controlled impurity level. Zone refining has removed many of the harmful elements in silicon. It has tended to homogenize commercial silicon to a definite impurity level generally limited by the presence of boron. It has permitted the recovery of silicon that is normally lost to the process. Finally it has yielded single crystal silicon with very favorable bulk characteristics as evidenced by resistivity and lifetime measurements.

ACKNOWLEDGEMENTS

The work reported here has been supported by the U.S.A.F. Air Materiel Command under Contract No. AF-33 (600) 28956. Also, the writer wishes to acknowledge the contributions made to this paper by his many associates in the General Electric Company. In particular he appreciates the contributions made by Dr. F. H. Horn and Dr. L. V. McCarty of the General Electric Company Research Laboratory. He further wishes to acknowledge contributions made by W. W. Schultz of the General Electric Company, General Engineering Laboratory. In the Semiconductor Products Department, the writer wishes to acknowledge contributions made to this paper by L. M. Downes, A. S. Rugare, J. E. Greever, and P. L. Ostapkovich.* The writer is also indebted to Dr. W. G. Pfann for the use of curves extracted from his paper entitled "Principles of Zone Melting," July 1952, Journal of Metals, Pages 748-751.

*Mr. P. L. Ostapkovich is now associated with the IBM in Poughkeepsie, N.Y.

CHARACTERISTICS CHART OF NEW DIODES and RECTIFIERS

MANUFACTURERS

(In Order of Code Letters)

AMP—	**Amperex Electronic Corp.**
AUD—	**Audio Devices, Inc.**
AUT—	**Automatic Mfg. Co.**
BEN—	**Bendix Aviation Corp.**
BER—	**Berkshire Labs**
BOG—	**Bogue Electric Mfg. Co.**
BOM—	**Bomac Labs**
BRA—	**Bradley Labs**
BTHB—	**British Thomson-Houston Export Co., Ltd.**
CBS—	**CBS-Hytron**
CTP—	**Clevite Transistor Products, Inc.**
CSF—	**Compagnie Generale de T.S.F.**
EEVB—	**English Electric Valve Co., Ltd.**
FAN—	**Fansteel Metallurgical Corp.**
GAH—	**Gahagan, Inc.**
GECB—	**General Electric Co., Ltd.**
GE—	**General Electric Company, Semiconductor Div.**
GTC—	**General Transistor Corp.**
HSD—	**Hoffman Semiconductor Division**
HUG—	**Hughes Products Division**
IFHS—	**Institutet for Halvledarforskning**
INRC—	**International Rectifier Corp.**
IRC—	**International Resistance Co.**
ITT—	**International Tel. & Tel. Corp.**
KEM—	**Kemtron Electron Products, Inc.**
LCTF—	**Laboratoire Central de Telecommunications**
MIC—	**Microwave Associates, Inc.**
MOT—	**Motorola, Inc.**
MUL—	**Mullard, Ltd.**
NAE—	**North American Electronics**
NPC—	**Nucleonic Products Co., Inc.**
PHI—	**Philco Corp., Lansdale Tube Company**
PSI—	**Pacific Semiconductors, Inc.**
QSC—	**Qutronic Semiconductor Corp.**
RAY—	**Raytheon Manufacturing Company**
RCA—	**Radio Corporation of America, Semiconductor Div**
RRC—	**Radio Receptor Co., Inc.**
SAR—	**Sarkes Tarzian, Inc., Rectifier Division**
SIE—	**Siemens & Halske Aktiengesellschaft**
SSD—	**Sperry Semiconductor Division**
STC—	**Shockley Transistor Corp.**
STCB—	**Standard Telephone & Cables, Ltd.**
SYL—	**Sylvania Electric Products, Inc.**
TFKG—	**Telefunken, Ltd.**
THE—	**Thermosen, Inc.**
TI—	**Texas Instruments, Inc.**
TKD—	**Tekade, Nurnberg, Germany**
TOK—	**Tokyo Tsushin Kogyo, Ltd.**
TRA—	**Transitron Electronic Corp.**
TSC—	**Trans-Sil Corp.**
USD—	**United States Dynamics Corp.**
USS—	**U. S. Semiconductor Products, Inc.**
WEC—	**Western Electric Co.**
WEST—	**Westinghouse Electric Corp.**

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
1N1644	1	Si	50	50		.750 @ 50	0.5	400 @ 50 @ 150	FAN
1N1645	1	Si	100	100		.750 @ 50	0.5	400 @ 100 @ 150	FAN
1N1646	1	Si	150	150		.750 @ 50	0.5	300 @ 150 @ 150	FAN
1N1647	1	Si	200	200		.750 @ 50	0.5	300 @ 200 @ 150	FAN
1N1648	1	Si	250	250		.750 @ 50	0.5	300 @ 250 @ 150	FAN
1N1649	1	Si	300	300		.750 @ 50	0.5	300 @ 300 @ 150	FAN
1N1650	1	Si	350	350		.750 @ 50	0.5	300 @ 350 @ 150	FAN
1N1651	1	Si	400	400		.750 @ 50	0.5	300 @ 400 @ 150	FAN
1N1652	1	Si	500	500		.750 @ 50	0.5	300 @ 500 @ 150	FAN
1N1653	1	Si	600	600		.750 @ 50	0.5	300 @ 600 @ 150	FAN
1N1763	1, 2	Si	400		15 amps @ 3	0.5† @ 75A		100 @ 400 @ 25A	RCA
1N1764	1, 2	Si	500		15 amps @ 3	0.5† @ 75A		100 @ 500 @ 25A	RCA
					† For half wave capacitive load averaged over 1 cycle.				
1N1839	1	Si	6.8	9.1	50 @ 1.0	130 ma @ 25	1.1	.5 @ 6.8 @ 25	USS
1N1840	1	Si	10	13	35 @ 1.0	115 ma @ 25	1.3	.5 @ 10 @ 25	USS
1N1841	1	Si	15	20	23 @ 1.0	95 ma @ 25	1.5	.5 @ 15 @ 25	USS
1N1842	1	Si	22	30	12 @ 1.0	75 ma @ 25	2	.1 @ 22 @ 25	USS
1N1843	1	Si	33	43	7 @ 1.0	60 ma @ 25	2	.1 @ 33 @ 25	USS
1N1844	1	Si	47	62	4.5 @ 1.0	45 ma @ 25	3	.1 @ 47 @ 25	USS
1N1845	1	Si	68	91	2.7 @ 1.0	36 ma @ 25	4	1.0 @ 68 @ 25	USS
1N1846	1	Si	100	130	1.5 @ 1.0	25 ma @ 25	6	1.0 @ 100 @ 25	USS
1N1847	1	Si	150	200	1.0 @ 1.0	17 ma @ 25	9	3.0 @ 150 @ 25	USS
1N1848	1	Si	220	300	6.5 @ 4.0	14 ma @ 25	11	5.0 @ 220 @ 25	USS
1N1849	1	Si	330	430	3.0 @ 4.0	12 ma @ 25	13	5.0 @ 330 @ 25	USS
1N1850	1	Si	470	620	2.0 @ 4.0	10 ma @ 25	15	5.0 @ 470 @ 25	USS
1N1851	1	Si	6.8	9.1	50 @ 1.0	130 ma @ 25	3	.5 @ 6.8 @ 25	USS
1N1852	1	Si	10	13	35 @ 1.0	115 ma @ 25	3.4	.5 @ 10 @ 25	USS
1N1853	1	Si	15	20	23 @ 1.0	95 ma @ 25	4	.5 @ 15 @ 25	USS
1N1854	1	Si	22	30	12 @ 1.0	75 ma @ 25	5	.1 @ 22 @ 25	USS
1N1855	1	Si	33	43	7 @ 1.0	60 ma @ 25	6	.1 @ 33 @ 25	USS

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_c @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
1N1856	1	Si	47	62	4.5 @ 1.0	45 ma @ 25	8	.1 @ 47 @ 25	USS
1N1857	1	Si	68	91	2.7 @ 1.0	36 ma @ 25	10	1.0 @ 68 @ 25	USS
1N1858	1	Si	100	130	1.5 @ 1.0	25 ma @ 25	16	1.0 @ 100 @ 25	USS
1N1859	1	Si	150	200	1.0 @ 1.0	17 ma @ 25	22	3.0 @ 150 @ 25	USS
1N1860	1	Si	220	300	6.5 @ 4.0	14 ma @ 25	28	5.0 @ 220 @ 25	USS
1N1861	1	Si	330	430	3.0 @ 4.0	12 ma @ 25	32	5.0 @ 330 @ 25	USS
1N1862	1	Si	470	620	2.0 @ 4.0	10 ma @ 25	40	5.0 @ 470 @ 25	USS
1N1863	1	Si	6.8	9.1	50 @ 1.0	130 ma @ 25	1.9	.5 @ 6.8 @ 25	USS
1N1864	1	Si	10	13	35 @ 1.0	115 ma @ 25	2.1	.5 @ 10 @ 25	USS
1N1865	1	Si	15	20	23 @ 1.0	95 ma @ 25	2.6	.5 @ 15 @ 25	USS
1N1866	1	Si	22	30	12 @ 1.0	75 ma @ 25	3	.1 @ 22 @ 25	USS
1N1867	1	Si	33	43	7 @ 1.0	60 ma @ 25	4	.1 @ 33 @ 25	USS
1N1868	1	Si	47	62	4.5 @ 1.0	45 ma @ 25	5	.1 @ 47 @ 25	USS
1N1869	1	Si	68	91	2.7 @ 1.0	36 ma @ 25	7	1.0 @ 68 @ 25	USS
1N1870	1	Si	100	130	1.5 @ 1.0	25 ma @ 25	10	1.0 @ 100 @ 25	USS
1N1871	1	Si	150	200	1.0 @ 1.0	17 ma @ 25	14	3.0 @ 150 @ 25	USS
1N1872	1	Si	220	300	6.5 @ 4.0	14 ma @ 25	18	5.0 @ 220 @ 25	USS
1N1873	1	Si	330	430	3.0 @ 4.0	12 ma @ 25	20	5.0 @ 330 @ 25	USS
1N1874	1	Si	470	620	2.0 @ 4.0	10 ma @ 25	25	5.0 @ 470 @ 25	USS
1N1907	2	Si	50	35	1000 @ 1	2.5	1.2	10 @ 50 @ 25	USS
1N1908	2	Si	100	70	1000 @ 1	2.5	1.2	10 @ 100 @ 25	USS
1N1909	2	Si	200	140	1000 @ 1	2.5	1.2	10 @ 200 @ 25	USS
1N1910	2	Si	300	210	1000 @ 1	2.5	1.2	10 @ 300 @ 25	USS
1N1911	2	Si	400	280	1000 @ 1	2.5	1.2	10 @ 400 @ 25	USS
1N1912	2	Si	500	350	1000 @ 1	2.5	1.2	10 @ 500 @ 25	USS
1N1913	2	Si	600	435	1000 @ 1	2.5	1.2	10 @ 600 @ 25	USS
1N1914	2	Si	700	500	1000 @ 1	2.5	1.2	10 @ 700 @ 25	USS
1N1915	2	Si	800	570	1000 @ 1	2.5	1.2	10 @ 800 @ 25	USS
1N1916	2	Si	900	630	1000 @ 1	2.5	1.2	10 @ 900 @ 25	USS
1N1917	2	Si	50	35	1000 @ 1	7	1.2	10 @ 50 @ 25	USS
1N1918	2	Si	100	70	1000 @ 1	7	1.2	10 @ 100 @ 25	USS
1N1919	2	Si	200	140	1000 @ 1	7	1.2	10 @ 200 @ 25	USS
1N1920	2	Si	300	210	1000 @ 1	7	1.2	10 @ 300 @ 25	USS
1N1921	2	Si	400	280	1000 @ 1	7	1.2	10 @ 400 @ 25	USS
1N1922	2	Si	500	350	1000 @ 1	7	1.2	10 @ 500 @ 25	USS
1N1923	2	Si	600	435	1000 @ 1	7	1.2	10 @ 600 @ 25	USS
1N1924	2	Si	700	500	1000 @ 1	7	1.2	10 @ 700 @ 25	USS
1N1925	2	Si	800	570	1000 @ 1	7	1.2	10 @ 800 @ 25	USS
1N1926			900	630	1A @ 1	7	1.2	10 @ 900	USS
1N2087	2	Si	400			.500 @ 100	1.5	1000 @ 400 @ 25	SAR
1N2088	2	Si	500			.750 @ 55	1.5	2000 @ 500 @ 25	SAR
1N2089	2	Si	600			.750 @ 55	1.5	2000 @ 600 @ 25	SAR
130	1	Se	46	26	.25 @ 2	.25 ma @ 55	2	4 @ 26 @ 25	IRC
150	1	Se	46	26	.50 @ 2	.50 ma @ 55	2	8 @ 26 @ 25	IRC
170	1	Se	46	26	1.0 @ 2	1.0 ma @ 55	2	16 @ 26 @ 25	IRC
230	1	Se	92	52	.25 @ 4	.25 ma @ 55	4	4 @ 52 @ 25	IRC
250	1	Se	92	52	.50 @ 4	.50 ma @ 55	4	8 @ 52 @ 25	IRC
270	1	Se	92	52	1.0 @ 4	1.0 ma @ 55	4	16 @ 52 @ 25	IRC
1158	1	Se	380	220		0.010* @ 50	3.6		ITT
1714	1	Se	210	88	16 @ 4	0.035 @ 70			ITT
1888	1	Se	150	66		0.020 @ 35	2.5		ITT
1946	1	Se	150	66		0.035 @ 35	2.5		ITT
						* Capacitive Load			
2W3A	2	Si	360			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W4A	2	Si	450			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W5A	2	Si	540			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W6A	2	Si	675			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W7A	2	Si	720			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W9A	2	Si	900			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W12A	2	Si	1200			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W15A	2	Si	1500			.175 @ 25C	2.0	200 @ @ 150C	TRA
2W20A	2	Si	2000			.175 @ 25C	2.0	200 @ @ 150C	TRA
9PA3‡	1	Se	138	78	1.0 @ 6	1.0 ma @ 55	6	16 @ 78 @ 25	IRC
9PA125	1	Se	5750	3250	1.0 @ 250	.2 ma @ 55	125	16 @ 3250 @ 25	IRC[6]
‡ Intermediate ratings available in increments of 46 volts PIV.									
10B3	2	Si	100			0.75 @ 100	1.4	1000 @ 100 @ 100	AUD
10B5	2	Si	100			0.50 @ 100	1.4	1000 @ 100 @ 100	AUD
20B3	2	Si	200			0.75 @ 100	1.4	1000 @ 200 @ 100	AUD
20B5	2	Si	200			0.50 @ 100	1.4	1000 @ 200 @ 100	AUD
30B3	2	Si	300			0.75 @ 100	1.4	1000 @ 300 @ 100	AUD
30B5	2	Si	300			0.50 @ 100	1.4	1000 @ 300 @ 100	AUD
40B3	2	Si	400			0.75 @ 100	1.4	1000 @ 400 @ 100	AUD
40B5	2	Si	400			0.50 @ 100	1.4	1000 @ 400 @ 100	AUD
50B3	2	Si	500			0.75 @ 100	1.4	1000 @ 500 @ 100	AUD
50B5	2	Si	500			0.50 @ 100	1.4	1000 @ 500 @ 100	AUD
B200	2	Si	360			0.20 @ 100	2.0	4000 @ 360 @ 25	AUD
CA102AA	2	Si	50	50		1 0 @ 75A	1.2	300 @ 50 @ 125C	ITT
CA102BA	2	Si	100	100		1.0 @ 75A	1.2	300 @ 100 @ 125C	ITT
CA102DA	2	Si	200	200		1.0 @ 75A	1.2	300 @ 200 @ 125C	ITT
CA102FA	2	Si	300	300		1.0 @ 75A	1.2	300 @ 300 @ 125C	ITT
CA102HA	2	Si	400	400		1.0 @ 75A	1.2	300 @ 400 @ 125C	ITT
CA102KA	2	Si	500	500		1.0 @ 74A	1.2	300 @ 500 @ 125C	ITT
CA102MA	2	Si	600	600		1.0 @ 75A	1.2	300 @ 600 @ 125C	ITT

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CC102AA	2	Si	50	50			1.0 @ 75A	1.2	300 @	50 @	125C	ITT
CC102BA	2	Si	100	100			1.0 @ 75A	1.2	300 @	100 @	125C	ITT
CC102DA	2	Si	200	200			1.0 @ 75A	1.2	300 @	200 @	125C	ITT
CC102FA	2	Si	300	300			1.0 @ 75A	1.2	300 @	300 @	125C	ITT
CC102HA	2	Si	400	400			1.0 @ 75A	1.2	300 @	400 @	125C	ITT
CC102KA	2	Si	500	500			1.0 @ 75A	1.2	300 @	500 @	125C	ITT
CC102MA	2	Si	600	600			1.0 @ 75A	1.2	300 @	600 @	125C	ITT
CE302AA	2	Si	50	50	1000 @	1.2	3.0 @ 50A		300 @	50 @	125C	ITT
CE302BA	2	Si	100	100	1000 @	1.2	3.0 @ 50A		300 @	100 @	125C	ITT
CE302DA	2	Si	200	200	1000 @	1.2	3.0 @ 50A		300 @	200 @	125C	ITT
CE302FA	2	Si	300	300	1000 @	1.2	3.0 @ 50A		300 @	300 @	125C	ITT
CE302HA	2	Si	400	400	1000 @	1.2	3.0 @ 50A		300 @	400 @	125C	ITT
CE302KA	2	Si	500	500	1000 @	1.2	3.0 @ 50A		300 @	500 @	125C	ITT
CE302MA	2	Si	600	600	1000 @	1.2	3.0 @ 50A		300 @	600 @	125C	ITT
CS302AA	2	Si	50	50	1000 @	1.2	3.0 @ 50A		300 @	50 @	125C	ITT
CS302BA	2	Si	100	100	1000 @	1.2	3.0 @ 50A		300 @	100 @	125C	ITT
CS302DA	2	Si	200	200	1000 @	1.2	3.0 @ 50A		300 @	200 @	125C	ITT
CS302FA	2	Si	300	300	1000 @	1.2	3.0 @ 50A		300 @	300 @	125C	ITT
CS302HA	2	Si	400	400	1000 @	1.2	3.0 @ 50A		300 @	400 @	125C	ITT
CS302KA	2	Si	500	500	1000 @	1.2	3.0 @ 50A		300 @	500 @	125C	ITT
CS302MA	2	Si	600	600	1000 @	1.2	3.0 @ 50A		300 @	600 @	125C	ITT
HA151	1	Si	100	100			0.150* @ 100A	1.2	500 @	100 @	100A	ITT
HA152	1	Si	200	200			0.150* @ 100A	1.2	500 @	200 @	100A	ITT
HA153	1	Si	300	300			0.150* @ 100A	1.2	500 @	300 @	100A	ITT
HA154	1	Si	400	400			0.150* @ 100A	1.2	500 @	400 @	100A	ITT
HA201	1	Si	100	100			0.200* @ 100A	1.2	500 @	100 @	100A	ITT
HA202	1	Si	200	200			0.200* @ 100A	1.2	500 @	200 @	100A	ITT
HA203	1	Si	300	300			0.200* @ 100A	1.2	500 @	300 @	100A	ITT
HA204	1	Si	400	400			0.200* @ 100A	1.2	500 @	400 @	100A	ITT
HA501	1	Si	100	100			0.500* @ 100A	1.2	500 @	100 @	100A	ITT
HA502	1	Si	200	200			0.500* @ 100A	1.2	500 @	200 @	100A	ITT
HA503	1	Si	300	300			0.500* @ 100A	1.2	500 @	300 @	100A	ITT
HA504	1	Si	400	400			0.500* @ 100A	1.2	500 @	400 @	100A	ITT
							* Capacitive Load					
HE151	1	Si	100	100			0.150* @ 100A	1.2	500 @	100 @	100A	ITT
HE152	1	Si	200	200			0.150* @ 100A	1 2	500 @	200 @	100A	ITT
HE153	1	Si	300	300			0.150* @ 100A	1.2	500 @	300 @	100A	ITT
HE154	1	Si	400	400			0.150* @ 100A	1.2	500 @	400 @	100A	ITT
HE201	1	Si	100	100			0.200* @ 100A	1.2	500 @	100 @	100A	ITT
HE202	1	Si	200	200			0.200* @ 100A	1.2	500 @	200 @	100A	ITT
HE203	1	Si	300	300			0.200* @ 100A	1.2	500 @	300 @	100A	ITT
HE204	1	Si	400	400			0.200* @ 100A	1.2	500 @	400 @	100A	ITT
HE501	1	Si	100	100			0.500* @ 100A	1.2	500 @	100 @	100A	ITT
HE502	1	Si	200	200			0.500* @ 100A	1.2	500 @	200 @	100A	ITT
HE503	1	Si	300	300			0.500* @ 100A	1.2	500 @	300 @	100A	ITT
HE504	1	Si	400	400			0.500* @ 100A	1.2	500 @	400 @	100A	ITT
HF151	1	Si	100	100			0.150* @ 100A	1.2	500 @	100 @	100A	ITT
HF152	1	Si	200	200			0.150* @ 100A	1.2	500 @	200 @	100A	ITT
HF153	1	Si	300	300			0.150* @ 100A	1.2	500 @	300 @	100A	ITT
HF154	1	Si	400	400			0.150* @ 100A	1.2	500 @	400 @	100A	ITT
HF201	1	Si	100	100			0.200* @ 100A	1.2	500 @	100 @	100A	ITT
HF202	1	Si	200	200			0.200* @ 100A	1.2	500 @	200 @	100A	ITT
HF203	1	Si	300	300			0.200* @ 100A	1.2	500 @	300 @	100A	ITT
HF204	1	Si	400	400			0.200* @ 100A	1.2	500 @	400 @	100A	ITT
							* Capacitive Load					
HF501	1	Si	100	100			0.500* @ 100A	1.2	500 @	100 @	100A	ITT
HF502	1	Si	200	200			0.500* @ 100A	1.2	500 @	200 @	100A	ITT
HF503	1	Si	300	300			0.500* @ 100A	1.2	500 @	300 @	100A	ITT
HF504	1	Si	400	400			0.500* @ 100A	1.2	500 @	400 @	100A	ITT
HR10741	2	Si	50				1.5 @ 135	1.5	150 @	50 @	150C	HUG
HR10743	2	Si	100				1.5 @ 135	1.5	150 @	100 @	150C	HUG
HR10745	2	Si	200				1.5 @ 135	1.5	150 @	200 @	150C	HUG
HR10747	2	Si	300				1.5 @ 135	1.5	150 @	300 @	150C	HUG
HR10749	2	Si	400				1.5 @ 135	1.5	150 @	400 @	150C	HUG
K1734	1	Se	380	220			0.050* @ 50	3.6				ITT
LRR-50			50	35	500 @	1.2	1.5	1.5	1 @	50		USS
LRR-100			100	70	500 @	1.2	1.5	1.5	1 @	100		USS
LRR-200			200	140	500 @	1.2	1.5	1.5	1 @	200		USS
LRR-300			300	210	500 @	1.2	1.5	1.5	1 @	300		USS
LRR-400			400	280	500 @	1.2	1.5	1.5	1 @	400		USS
LRR-500			500	350	500 @	1.2	1.5	1.5	1 @	500		USS

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

5. Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
N5082A	2	Si	50			150 @ 25	0.65	40 ma @ 50 @ 25	WEST
N5082B	2	Si	100			150 @ 25	0.65	40 ma @ 100 @ 25	WEST
N5082C	2	Si	150			150 @ 25	0.65	40 ma @ 150 @ 25	WEST
N5082D	2	Si	200			150 @ 25	0.65	40 ma @ 150 @ 25	WEST
N5082E	2	Si	250			150 @ 25	0.65	40 ma @ 250 @ 25	WEST
N5082F	2	Si	300			150 @ 25	0.65	40 ma @ 300 @ 25	WEST
N5082G	2	Si	350			150 @ 25	0.65	40 ma @ 350 @ 25	WEST
N5082H	2	Si	400			150 @ 25	0.65	40 ma @ 400 @ 25	WEST
NA1	2	Si	50	50	2000 @ 2	1.0 @ 100	2	300 @ 50 @ 100	NAE
NA2	2	Si	50	50	800 @ 2	.40 @ 100	2	300 @ 50 @ 100	NAE
NA3	2	Si	50	50	400 @ 2	.20 @ 100	2	300 @ 50 @ 100	NAE
NA4	2	Si	50	50	2000 @ 2	1.0 @ 100	2	500 @ 50 @ 100	NAE
NA5	2	Si	50	50	800 @ 2	.40 @ 100	2	500 @ 50 @ 100	NAE
NA7	2	Si	50	50	6000 @ 1.5	3.0 @ 150	1.5	500 @ 50 @ 150	NAE
NA11	2	Si	100	100	2000 @ 2	1.0 @ 100	2	300 @ 100 @ 100	NAE
NA12	2	Si	100	100	800 @ 2	.40 @ 100	2	300 @ 100 @ 100	NAE
NA13	2	Si	100	100	400 @ 2	.20 @ 100	2	300 @ 100 @ 100	NAE
NA17	2	Si	100	100	6000 @ 1.5	3.0 @ 150	1.5	500 @ 100 @ 150	NAE
NA21	2	Si	200	200	2000 @ 2	1.0 @ 100	2	300 @ 200 @ 100	NAE
NA22	2	Si	200	200	800 @ 2	.40 @ 100	2	300 @ 200 @ 100	NAE
NA23	2	Si	200	200	400 @ 2	.20 @ 100	2	300 @ 200 @ 100	NAE
NA24	2	Si	200	200	2000 @ 2	1.0 @ 150	2	300 @ 200 @ 150	NAE
NA25	3	Si	200	200	800 @ 2	.40 @ 150	2	50 @ 200 @ 150	NAE
NA27	2	Si	200	200	6000 @ 1.5	3.0 @ 150	1.5	500 @ 200 @ 150	NAE
NA31	2	Si	300	300	2000 @ 2	1.0 @ 100	2	300 @ 300 @ 100	NAE
NA32	2	Si	300	300	800 @ 2	.40 @ 100	2	300 @ 300 @ 100	NAE
NA33	2	Si	300	300	400 @ 2	.20 @ 100	2	300 @ 300 @ 100	NAE
NA34	2	Si	300	300	2000 @ 2	1.0 @ 150	2	500 @ 300 @ 150	NAE
NA35	3	Si	300	300	800 @ 2	.40 @ 150	2	100 @ 300 @ 150	NAE
NA36	3	Si	300	300	400 @ 2	.20 @ 150	2	100 @ 300 @ 150	NAE
NA37	2	Si	300	300	6000 @ 1.5	3.0 @ 150	1.5	500 @ 300 @ 150	NAE
NA41	2	Si	400	400	2000 @ 2	1.0 @ 100	2	300 @ 400 @ 100	NAE
NA42	2	Si	400	400	800 @ 2	.40 @ 100	2	300 @ 400 @ 100	NAE
NA43	2	Si	400	400	400 @ 2	.20 @ 100	2	300 @ 400 @ 100	NAE
NA44	2	Si	400	400	2000 @ 2	1.0 @ 150	2	500 @ 400 @ 150	NAE
NA45	3	Si	400	400	800 @ 2	.40 @ 150	2	100 @ 400 @ 150	NAE
NA46	3	Si	400	400	400 @ 2	.20 @ 150	2	100 @ 400 @ 150	NAE
NA47	2	Si	400	400	6000 @ 1.5	3.0 @ 150	1.5	500 @ 400 @ 150	NAE
NA51	2	Si	500	500	2000 @ 2	1.0 @ 100	2	300 @ 500 @ 100	NAE
NA52	2	Si	500	500	800 @ 2	.40 @ 100	2	300 @ 500 @ 100	NAE
NA53	2	Si	500	500	400 @ 2	.20 @ 100	2	300 @ 500 @ 100	NAE
NA54	2	Si	500	500	2000 @ 2	1.0 @ 150	2	500 @ 500 @ 150	NAE
NA55	2	Si	500	500	800 @ 2	.40 @ 150	2	500 @ 500 @ 150	NAE
NA56	2	Si	500	500	400 @ 2	.20 @ 150	2	500 @ 500 @ 150	NAE
NA57	2	Si	500	500	6000 @ 1.5	3.0 @ 150	1.5	500 @ 500 @ 150	NAE
NA61	2	Si	600	600	2000 @ 2	1.0 @ 100	2	300 @ 600 @ 100	NAE
NA62	2	Si	600	600	800 @ 2	.40 @ 100	2	300 @ 600 @ 100	NAE
NA63	2	Si	600	600	400 @ 2	.20 @ 100	2	300 @ 600 @ 100	NAE
NA64	2	Si	600	600	2000 @ 2	1.0 @ 150	2	500 @ 600 @ 150	NAE
NA65	2	Si	600	600	800 @ 2	.40 @ 150	2	500 @ 600 @ 150	NAE
NA66	2	Si	600	600	400 @ 2	.20 @ 150	2	500 @ 600 @ 150	NAE
NA67	2	Si	600	600	6000 @ 1.5	3.0 @ 150	1.5	500 @ 600 @ 150	NAE
NA74	2	Si	700	700	2000 @ 2	1.0 @ 125	2	500 @ 700 @ 125	NAE
NA75	2	Si	700	700	800 @ 2	.40 @ 125	2	500 @ 700 @ 125	NAE
NA76	2	Si	700	700	400 @ 2	.20 @ 125	2	500 @ 700 @ 125	NAE
NA84	2	Si	800	800	2000 @ 2	1.0 @ 125	2	500 @ 800 @ 125	NAE
NA85	2	Si	800	800	800 @ 2	.40 @ 125	2	500 @ 800 @ 125	NAE
NA86	2	Si	800	800	400 @ 2	.20 @ 125	2	500 @ 800 @ 125	NAE
NA104	2	Si	1000	1000	2000 @ 2	1.0 @ 125	2	500 @ 1000 @ 125	NAE
NA105	2	Si	1000	1000	800 @ 2	.40 @ 125	2	500 @ 1000 @ 125	NAE
NA106	2	Si	1000	1000	400 @ 2	.20 @ 125	2	500 @ 1000 @ 125	NAE
NA124	2	Si	1200	1200	200 @ 2	1.0 @ 125	2	500 @ 1200 @ 125	NAE
NA125	2	Si	1200	1200	800 @ 2	.40 @ 125	2	500 @ 1200 @ 125	NAE
NA126	2	Si	1200	1200	400 @ 2	.20 @ 125	2	500 @ 1200 @ 125	NAE
NA150	2	Si	1500		300 @ 7.5			50 @ 1500 @ 25	NAE
NA150R	2	Si	1500		300 @ 7.5			50 @ 1500 @ 25	NAE
NA151	2	Si	1800		300 @ 12			50 @ 1800 @ 25	NAE
NA152	2	Si	2000		300 @ 12			50 @ 2000 @ 25	NAE
NL5	2	Si	50	50	500 @ 1.5	.50 @ 100	1.5	1000 @ 50 @ 100	NAE
NL10	2	Si	100	100	500 @ 1.5	.50 @ 100	1.5	1000 @ 100 @ 100	NAE
NL15	2	Si	150	150	500 @ 1.5	.50 @ 100	1.5	1000 @ 150 @ 100	NAE
NL20	2	Si	200	200	500 @ 1.5	.50 @ 100	1.5	1000 @ 200 @ 100	NAE
NL25	2	Si	250	250	500 @ 1.5	.50 @ 100	1.5	1000 @ 250 @ 100	NAE
NL30	2	Si	300	300	500 @ 1.5	.50 @ 100	1.5	1000 @ 300 @ 100	NAE
NL40	2	Si	400	400	500 @ 1.5	.50 @ 100	1.5	1000 @ 400 @ 100	NAE
NL50	2	Si	500	500	500 @ 1.5	.50 @ 100	1.5	1000 @ 500 @ 100	NAE
NA0305	2	Si	30	30		5.0 @ 150	1.25	5000 @ 30 @ 150	NAE
NA0310	2	Si	30	30		10 @ 150	1.25	5000 @ 30 @ 150	NAE
NA0320	2	Si	30	30		20 @ 150	1.25	5000 @ 30 @ 150	NAE
NA0505	2	Si	50	50		5.0 @ 150	1.25	5000 @ 50 @ 150	NAE
NA0510	2	Si	50	50		10 @ 150	1.25	5000 @ 50 @ 150	NAE
NA0520	2	Si	50	50		20 @ 150	1.25	5000 @ 50 @ 150	NAE
NA1005	2	Si	100	100		5.0 @ 150	1.25	5000 @ 100 @ 150	NAE

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
NA1010	2	Si	100	100		10 @ 150	1.25	5000 @ 100 @ 150	NAE
NA1020	2	Si	100	100		20 @ 150	1.25	5000 @ 100 @ 150	NAE
NA1505	2	Si	150	150		5.0 @ 150	1.25	5000 @ 150 @ 150	NAE
NA1510	2	Si	150	150		10 @ 150	1.25	5000 @ 150 @ 150	NAE
NA1520	2	Si	150	150		20 @ 150	1.25	5000 @ 150 @ 150	NAE
NA2005	2	Si	200	200		5.0 @ 150	1.25	5000 @ 200 @ 150	NAE
NA2010	2	Si	200	200		10 @ 150	1.25	5000 @ 200 @ 150	NAE
NA2020	2	Si	200	200		20 @ 150	1.25	5000 @ 200 @ 150	NAE
NA2505	2	Si	250	250		5.0 @ 150	1.25	5000 @ 250 @ 150	NAE
NA2510	2	Si	250	250		10 @ 150	1.25	5000 @ 250 @ 150	NAE
NA2520	2	Si	250	250		20 @ 150	1.25	5000 @ 250 @ 150	NAE
NA3005	2	Si	300	300		5.0 @ 150	1.25	5000 @ 300 @ 150	NAE
NA3010	2	Si	300	300		10 @ 150	1.25	5000 @ 300 @ 150	NAE
NA3020	2	Si	300	300		20 @ 150	1.25	5000 @ 300 @ 150	NAE
NA3505	2	Si	350	350		5.0 @ 150	1.25	5000 @ 350 @ 150	NAE
NA3510	2	Si	350	350		10 @ 150	1.25	5000 @ 350 @ 150	NAE
NA3520	2	Si	350	350		20 @ 150	1.25	5000 @ 350 @ 150	NAE
NA4005	2	Si	400	400		5.0 @ 150	1.25	5000 @ 400 @ 150	NAE
NA4010	2	Si	400	400		10 @ 150	1.25	5000 @ 400 @ 150	NAE
NA4020	2	Si	400	400		20 @ 150	1.25	5000 @ 400 @ 150	NAE
R70	1, 2, 3	Si	700	700	3000 @ 1.0	1.0 @ 25	1.0	20 @ 700 @ .25	TSC[6]
R80	1, 2, 3	Si	800	800	3000 @ 1.0	1.0 @ 25	1.0	20 @ 800 @ .25	TSC[6]
R90	1, 2, 3	Si	900	900	3000 @ 1.0	1.0 @ 25	1.0	20 @ 900 @ .25	TSC[6]
R100	1, 2, 3	Si	1000	1000	3000 @ 1.0	1.0 @ 25	1.0	20 @ 1000 @ .25	TSC[6]
S9G	1	Si	40		2.0 @ 1.0			20 @ 30 @ 25	TRA
S10G	1	Si	15		100 @ 1.7			20 @ 10 @ 25	TRA
S70	1, 2, 3	Si	700	700	6000 @ 1.0	5.0 @ 25	1.0	20 @ 700 @ .25	TSC[6]
S80	1, 2, 3	Si	800	800	6000 @ 1.0	5.0 @ 25	1.0	20 @ 800 @ .25	TSC[6]
S90	1, 2, 3	Si	900	900	6000 @ 1.0	5.0 @ 25	1.0	20 @ 900 @ .25	TSC[6]
S100	1, 2, 3	Si	1000	1000	6000 @ 1.0	5.0 @ 25	1.0	20 @ 1000 @ .25	TSC[6]
S1134			1000	680	500 @ 1	1	2.5	100 @ 200	USS
S1134A			1000	680	500 @ 1	1	2.5	100 @ 200	USS
S1135			1500	950	500 @ 1	1	2.5	100 @ 200	USS
S1135A			1500	950	500 @ 1	1	2.5	100 @ 200	USS
S1136			1000	680	500 @ 1	1	2.5	100 @ 200	USS
S1136A			1000	680	500 @ 1	1	2.5	100 @ 200	USS
S1137			1500	950	500 @ 1	1	2.5	100 @ 200	USS
S1137A			1500	950	500 @ 1	1	2.5	100 @ 200	USS
T70	1, 2, 3	Si	700	700	15000 @ 1.0	10 @ 25	1.0	50 @ 700 @ 25	TSC[6]
T80	1, 2, 3	Si	800	800	15000 @ 1.0	10 @ 25	1.0	50 @ 800 @ 25	TSC[6]
TH152B	2	Si	150	105		50 @ 150C	1.5	15 ma @ 150 @ 150C	TRA
TH252B	2	Si	250	175		50 @ 150C	1.5	15 ma @ 250 @ 150C	TRA
TH302B	2	Si	300	210		50 @ 150C	1.5	15 ma @ 300 @ 150C	TRA
TH352B	2	Si	350	245		50 @ 150C	1.5	15 ma @ 350 @ 150C	TRA
TH402B	2	Si	400	280		50 @ 150C	1.5	15 ma @ 400 @ 150C	TRA
TJ5A	3	Si	50			.20 @ 150C	1.5	500	TRA
TJ10A	3	Si	100			.20 @ 150C	1.5	500	TRA
TJ15A	3	Si	150			.20 @ 150C	1.5	500	TRA
TJ20A	3	Si	200			.20 @ 150C	1.5	500	TRA
TJ25A	3	Si	250			.20 @ 150C	1.5	500	TRA
TJ30A	3	Si	300			.20 @ 150C	1.5	500	TRA
TJ35A	3	Si	350			.20 @ 150C	1.5	500	TRA
TJ40A	3	Si	400			.20 @ 150C	1.5	500	TRA
TJ60A	3	Si	600			.20 @ 150C	1.5	500	TRA
TM4	2	Si	50			1.0 @ 150C	2.0	500 @ 150C	TRA
TM7	2	Si	50			3.0 @ 150C	1.5	500	TRA
TM17	2	Si	100			3.0 @ 150C	1.5	500	TRA
TM24	2	Si	200			1.0 @ 150C	2.0	500 @ 150C	TRA
TM27	2	Si	200			3.0 @ 150C	1.5	500	TRA
TM34	2	Si	300			1.0 @ 150C	2.0	500 @ 150C	TRA
TM37	2	Si	300			3.0 @ 150C	1.5	500	TRA
TM44	2	Si	400			1.0 @ 150C	2.0	500 @ 150C	TRA
TM54	2	Si	500			1.0 @ 150C	2.0	500 @ 150C	TRA
TM57	2	Si	500			3.0 @ 150C	1.5	500	TRA
TM64	2	Si	600			1.0 @ 150C	2.0	500 @ 150C	TRA
TM67	2	Si	600			3.0 @ 150C	1.5	500	TRA
TM155	2	Si		1500		.40		500	TRA
TM156	2	Si		1500		.40		500	TRA
TR30	2	Si	30			20 @ 100C	2.0	10 ma @ 100C	TRA
TR50	2	Si	50			20 @ 100C	2.0	10 ma @ 100C	TRA
TR100	2	Si	100			20 @ 100C	2.0	10 ma @ 100C	TRA

NOTATIONS

Under Use

1. General Purpose
2. Power Rectifier
3. Magnetic Amplifier

Other

4. For half wave resistive load average over 1 cycle

Under Reverse Current

5. Dynamic

Under Mfr.

6. Available in stack form from that manufacturer

Following any temperature reading these symbols apply

A — Ambient
C — Case
J — Junction
S — Storage
* — Forced Convection — 2000LFM

Manufacturers should be contacted for value and test condition for surge current and maximum peak recurrent current.

CHARACTERISTICS CHART of DIODES and RECTIFIERS

TYPE NO.	USE (See Code Below)	MAT	PIV (volts)	MAX. CONT. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	MAX. D.C. OUTPUT CURRENT[4] @ T (°C) (amps)	MAX. FULL LOAD VOLT. DROP[4] (volts)	Max. Rev. Current I_b @ E_b @ T (uA) (volts) (°C)	MFR. (See code at start of charts)
TR150	2	Si	150			20 @ 100C	2.0	10 ma @ 100C	TRA
TR151	2	Si	150			10 @ 150C	1.5	5000 @ 150C	TRA
TR152	2	Si	150			20 @ 150C	1.5	5000 @ 150C	TRA
TR200	2	Si	200			20 @ 150C	2.0	10 ma @ 100C	TRA
TR251	2	Si	250			10 @ 150C	1.5	5000 @ 150C	TRA
TR252	2	Si	250			20 @ 150C	1.5	5000 @ 150C	TRA
TR301	2	Si	300			10 @ 150C	1.5	5000 @ 150C	TRA
TR302	2	Si	300			20 @ 150C	1.5	5000 @ 150C	TRA
TR351	2	Si	350			10 @ 150C	1.5	5000 @ 150C	TRA
TR352	2	Si	350			20 @ 150C	1.5	5000 @ 150C	TRA
TR401	2	Si	400			10 @ 150C	1.5	5000 @ 150C	TRA
TR402	2	Si	400			20 @ 150C	1.5	5000 @ 150C	TRA
USD142J	2	Si	500		1000 @ 1.0	3.0 @ 25	1.0	200 @ 500 @ 25	USD
USD145J	2	Si	500		1000 @ 1.0	3.0 @ 25	1.0	500 @ 500 @ 25	USD
USD162J	2	Si	500		5000 @ 1.2	5.0 @ 25	1.2	200 @ 500 @ 25	USD
USD5051J	2	Si	500		5000 @ 1.2	5.0 @ 25	1.2	5000 @ 500 @ 25	USD
USD5051L	2	Si	600		5000 @ 1.2	5.0 @ 25	1.2	5000 @ 600 @ 25	USD
USD5051P	2	Si	800		5000 @ 1.2	5.0 @ 25	1.2	5000 @ 800 @ 25	USD
USD5051T	2	Si	1000		5000 @ 1.2	5.0 @ 25	1.2	5000 @ 1000 @ 25	USD
USD5091J	2	Si	500		1000 @ 1.0	3.0 @ 25	1.0	5000 @ 500 @ 25	USD
USD5091L	2	Si	600		1000 @ 1.0	3.0 @ 25	1.0	5000 @ 600 @ 25	USD
USD5091P	2	Si	800		1000 @ 1.0	3.0 @ 25	1.0	5000 @ 800 @ 25	USD
USD5091T	2	Si	1000		1000 @ 1.0	3.0 @ 25	1.0	5000 @ 1000 @ 25	USD
ZJ39A25	4	Si	25			16 @ 80C	0.75	5000	GE
ZJ39A40	4	Si	40			16 @ 80C	0.75	5000	GE
ZJ39A75	4	Si	75			16 @ 80C	0.75	5000	GE
ZJ39A100	4	Si	100			16 @ 80C	0.75	5000	GE
ZJ39A150	4	Si	150			16 @ 80C	0.75	5000	GE
ZJ39A200	4	Si	200			16 @ 80C	0.75	5000	GE
ZJ39A250	4	Si	250			16 @ 80C	0.75	5000	GE
ZJ39A300	4	Si	300			16 @ 80C	0.75	5000	GE
ZJ39A400	4	Si	400			16 @ 80C	0.75	5000	GE
W5	1, 2, 3	Si	50	50		200 @ 25	1.0	1000 @ 50 @ 25	TSC[6]
W10	1, 2, 3	Si	100	100		200 @ 25	1.0	1000 @ 100 @ 25	TSC[6]
W20	1, 2, 3	Si	200	200		200 @ 25	1.0	1000 @ 200 @ 25	TSC[6]
W30	1, 2, 3	Si	300	300		200 @ 25	1.0	1000 @ 300 @ 25	TSC[6]
W40	1, 2, 3	Si	400	400		200 @ 25	1.0	1000 @ 400 @ 25	TSC[6]

CHARACTERISTICS CHART of MISCELLANEOUS DIODE TYPES

TYPE NO.	CLASSIFICATION	DESCRIPTION	MFR.
4N20-50DL	7	Breakdown—45 to 50 V. @ 0.5 ma, max holding —2 V. max 50 ma max, <4 V Amp for 3 Amp pulse	STC
NRD40		Negative Resistance Diode	USS
NRD60		Negative Resistance Diode	USS
NRD80		Negative Resistance Diode	USS
NRD90		Negative Resistance Diode	USS
NRD115		Negative Resistance Diode	USS
NRD130		Negative Resistance Diode	USS

NOTATIONS
Under Classification
7. 4-Layer Bistable Diode

THE FOLLOWING MANUFACTURERS HAVE ANNOUNCED THAT THEY HAVE BEGUN SUPPLYING THE INDICATED PREVIOUSLY REGISTERED DIODES AND RECTIFIERS

BENDIX: 1N536, 1N537, 1N538, 1N539, 1N540, 1N547
BOMAC: 1N21WE, 1N23WE
NORTH AMERICAN ELECTRONCIS: 1N253, 1N254, 1N255, 1N256, 1N332, 1N333, 1N334, 1N335, 1N336, 1N337, 1N338, 1N339, 1N340, 1N341, 1N342, 1N343, 1N344, 1N345, 1N346, 1N347, 1N348, 1N349, 1N550, 1N551, 1N552, 1N553, 1N554, 1N555, 1N607, 1N607A, 1N608, 1N608A, 1N610, 1N610A, 1N611, 1N611A, 1N612, 1N612A, 1N613, 1N613A, 1N614, 1N614A, 1N1115, 1N1116, 1N1117, 1N1118, 1N440B, 1N441B, 1N442B, 1N443B, 1N444B, 1N536, 1N537, 1N538, 1N539, 1N540, 1N547, 1N560, 1N561, 1N599, 1N599A, 1N600, 1N600A, 1N601, 1N601A, 1N602, 1N602A, 1N603, 1N603A, 1N604, 1N604A, 1N605, 1N605A, 1N606, 1N606A, 1N1095, 1N588, 1N589, 1N248, 1N248A, 1N249, 1N249A, 1N250, 1N250A, 1N1130, 1N1131, 1N1133, 1N1134, 1N1135, 1N1136, 1N1137, 1N1138, 1N1139, 1N1140, 1N1141, 1N1142, 1N1143, 1N1143A, 1N1144, 1N1145, 1N1146, 1N1147, 1N1148, 1N1149
NUCLEONICS: 1N81, 1N82, 1N119, 1N120, 1N147
SPERRY: 1N487, 1N487A, 1N625, 1N626, 1N627, 1N628, 1N629
TRANSITRON: 1N126, 1N127, 1N1133, 1N1134, 1N1135, 1N1136, 1N1137, 1N1138, 1N1139, 1N1140, 1N1141, 1N1142, 1N1143, 1N1143A, 1N1144, 1N1145, 1N1146, 1N1147, 1N1148, 1N1149
U.S. SEMICONDUCTOR PRODUCTS: 1N137A, 1N138A, 1N200, 1N201, 1N202, 1N203, 1N204, 1N205, 1N206, 1N207, 1N208, 1N209, 1N210, 1N211, 1N212, 1N213, 1N214, 1N215, 1N216, 1N217, 1N218, 1N219, 1N220, 1N221, 1N222, 1N225, 1N226, 1N227, 1N228, 1N229, 1N230, 1N231, 1N232, 1N233, 1N234, 1N235, 1N465, 1N466, 1N467, 1N468, 1N469, 1N470, 1N471, 1N472, 1N473, 1N474, 1N475, 1N536, 1N537, 1N538, 1N539, 1N540, 1N1095, 1N1313, 1N1314, 1N1315, 1N1316, 1N1317, 1N1318, 1N1319, 1N1320, 1N1321, 1N1322, 1N1323, 1N1324, 1N1325, 1N1326, 1N1327

CHARACTERISTICS CHART of SWITCHING DIODES

TYPE NO.	MAT	PIV (volts)	MAX. CONT. REV. WORK. VOLT. (volts)	Min. Forward Current @ 25°C I_f @ E_f (mA) (volts)	Reverse Impedance @ 25°C Z (K ohms)	Reverse Impedance @ 25°C VOLTAGE RANGE E_{b1} to E_{b2} (volts)	Recovery Characteristics TEST CONDITIONS Fwd. Rev. I_f to E_b (ma) (volts)	Recovery Characteristics $Z_{rec.}$ @ time (t) (K ohms) (usec)	MFR. (See code at start of charts)
Q3-90	Ge			100 @ 1.0	30	3.0	1.6 to 3.0	7.5 @ .001	QSC
Q4-100	Ge			100 @ 1.0	40	4.0	1.6 to 3.0	7.5 @ .001	QSC
Q4-500	Ge			100 @ 1.0	40	4.0	1.6 to 3.0	7.5 @ .008	QSC
Q5-500	Ge			100 @ 1.0	50	5.0	1.6 to 3.0	7.5 @ .008	QSC
Q6-500	Ge			100 @ 1.0	60	6.0	1.6 to 3.0	7.5 @ .008	QSC
Q10-250	Ge			100 @ 1.0	100	10	1.6 to 3.0	7.5 @ .005	QSC
Q10-950	Ge			100 @ 1.0	100	10	1.6 to 3.0	7.5 @ .015	QSC
Q20-250	Ge			50 @ 1.0	200	20	1.6 to 3.0	7.5 @ .005	QSC
Q20-500	Ge			50 @ 1.0	200	20	1.6 to 3.0	7.5 @ .008	QSC
Q20-750	Ge			50 @ 1.0	200	20	1.6 to 3.0	7.5 @ .012	QSC
Q20-950	Ge			50 @ 1.0	200	20	1.6 to 3.0	7.5 @ .015	QSC
Q30-500	Ge			50 @ 1.0	300	30	1.6 to 3.0	7.5 @ .008	QSC
Q30-950	Ge			50 @ 1.0	300	30	1.6 to 3.0	7.5 @ .015	QSC
Q40-500	Ge			50 @ 1.0	400	40	1.6 to 3.0	7.5 @ .008	QSC
Q40-750	Ge			50 @ 1.0	400	40	1.6 to 3.0	7.5 @ .012	QSC
Q40-950	Ge			50 @ 1.0	400	40	1.6 to 3.0	7.5 @ .015	QSC
Q50-500	Ge			50 @ 1.0	500	50	1.6 to 3.0	7.5 @ .008	QSC
Q50-750	Ge			50 @ 1.0	500	50	1.6 to 3.0	7.5 @ .012	QSC
Q50-950	Ge			50 @ 1.0	500	50	1.6 to 3.0	7.5 @ .015	QSC
Q60-500	Ge			50 @ 1.0	600	60	1.6 to 3.0	7.5 @ .008	QSC
Q60-750	Ge			50 @ 1.0	600	60	1.6 to 3.0	7.5 @ .012	QSC
Q60-950	Ge			50 @ 1.0	600	60	1.6 to 3.0	7.5 @ .015	QSC
Q80-500	Ge			50 @ 1.0	800	80	1.6 to 3.0	7.5 @ .008	QSC
Q80-750	Ge			50 @ 1.0	800	80	1.6 to 3.0	7.5 @ .012	QSC
Q80-950	Ge			50 @ 1.0	800	80	1.6 to 3.0	7.5 @ .015	QSC
Q100-500	Ge			50 @ 1.0	1000	100	1.6 to 3.0	7.5 @ .008	QSC
Q100-750	Ge			50 @ 1.0	1000	100	1.6 to 3.0	7.5 @ .012	QSC
Q100-950	Ge			50 @ 1.0	1000	100	1.6 to 3.0	7.5 @ .015	QSC
S266G	Si	8.0		10 @ 1.5	6000	6.0	10 to 6.0	.004	TRA
S555G	Ge	15		10 @ 1.5	600	6.0	10 to 6.0	.006	TRA
S570G	Ge	8.0		10 @ 1.0	200	6.0	10 to 6.0	.002	TRA
SG211	Si	80	70	5.0 @ 1.5		60	5.0 to 40	400 @ .30	TRA
SG212	Si	150	130	5.0 @ 1.5		125	5.0 to 40	400 @ .30	TRA
SG213	Si	200	180	5.0 @ 1.5		175	5.0 to 40	400 @ .30	TRA
SG215	Si	40	36	5.0 @ 1.5		30	5.0 to 40	400 @ 1.0	TRA
SG216	Si	80	70	5.0 @ 1.5		60	5.0 to 40	400 @ 1.0	TRA
SG217	Si	150	130	5.0 @ 1.5		125	5.0 to 40	400 @ 1.0	TRA
SG218	Si	200	180	5.0 @ 1.5		175	5.0 to 40	400 @ 1.0	TRA
SG221	Si	80	70	30 @ 1.5		60	20 to 40	80 @ .50	TRA
SG222	Si	150	130	30 @ 1.5		125	20 to 40	80 @ .50	TRA
SG223	Si	200	180	30 @ 1.5		175	20 to 40	80 @ .50	TRA
SG225	Si	40	36	100 @ 1.5		30	20 to 40	80 @ 1.0	TRA
SG226	Si	80	70	100 @ 1.5		60	20 to 40	80 @ 1.0	TRA
SG227	Si	150	130	100 @ 1.5		125	20 to 40	80 @ 1.0	TRA
SG228	Si	200	180	100 @ 1.5		175	20 to 40	80 @ 1.0	TRA

VOLTAGE VARIABLE CAPACITOR DIODES

TYPE NO.	CAPACITANCE C @ Eb (uuf)	CAPACITANCE C @ Eb (volts)	PIV	Q @ FREQ. Min. Q	Q @ FREQ. (mc)	MFR.
6.8SC20	6.8	10				INRC
V7	7	4	25	13	50	PSI
V7E	7	4	100	3	50	PSI
V10	10	4	25	13	50	PSI
V10E	10	4	100	3.5	50	PSI
V12	12	4	25	13	50	PSI
V12E	12	4	100	4	50	PSI
V15	15	4	25	13	50	PSI
V15E	15	4	100	4.5	50	PSI
V20E	20	4	70	7	50	PSI
V27E	27	4	65	7	50	PSI
V33E	33	4	60	7	50	PSI
V39E	39	4	55	7	50	PSI
V47E	47	4	50	7	50	PSI
V56E	56	4	40	7	50	PSI
V68	68	4	15	9	50	PSI
V82	82	4	15	9	50	PSI
V100	100	4	15	8	50	PSI

NOTICE: Characteristics Chart of Silicon Zener or Avalanche Diodes will appear in the January 1959 issue.

SEMICONDUCTOR & SOLID-STATE BIBLIOGRAPHY

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHORS
Oxides of the 3rd Transition metals	The Bell System Technical Journal July 1958	Magnetic, electrical, and optical properties are examined for clues to energy band structure.	F. J. Morin
Shot Noise in *p-n* Junction Frequency Converters	The Bell System Technical Journal July 1958	Equations are derived for the noise figure using a diode with arbitrary minority-carrier storage.	A. Uhlir Jr.
Amplitude Modulation Suppression in FM Systems	The Bell System Technical Journal July 1958	Inadequacies of some limiter concepts discussed; low-index modulation index theory presented.	C. L. Ruthroff
Gain and Noise Figure of a Variable-Capacitance Up-Converter	The Bell System Technical Journal July 1958	Performance of non-linear capacitance diode analyzed for multiplied output frequency.	D. Leenov
Low-Field Mobility of Carriers in Nondegenerate Semiconductors	Canadian Journal of Physics June 1958	Gunn's theory of the low-field variation of carrier mobility has been extended to include effect of scattering.	M. S. Sodka D. B. Agrawal
High-Efficiency Push-Pull Magnetic Amplifiers with transistors as switched rectifiers	Comm. and Electronics (AIEE) July 1958	Efficiencies well in excess of 50% for ± polarity-reversing *d-c* output are obtained.	A. G. Milnes
Minimization of Components in Electronic Switching Circuits	Comm. and Electronics (AIEE) July 1958	Minimization is considered only for circuits using diodes or transistors as switching elements.	T. J. Beatson
Transistorized Negative-Impedance Telephone Repeaters	Comm. and Electronics (AIEE) July 1958	Description and operation of commercial series and shunt type repeaters.	R. P. Dimmer
1000 MC Range Reached with Diffused Base Transistors	Electronic Design July 9, 1958	Two typical diffused base transistors are discussed in terms of their operating characteristics.	C. H. Knowles E. A. Temple
Transistor Impedance Nomogram	Electronic Design July 9, 1958	Generator R vs. output resistance (common C and common E), input R vs. load R (common C and common E).	T. R. Nisbet
Variation of Transistor Parameters with Temperature	Electronic Design July 9, 1958	Grounded emitter power gain, reverse voltage feedback (grounded base), collector current with base open, and H_{FE} discussed.	M. J. Maloney
Decade of Transistor Progress	Electronic Design July 9, 1958	Review of progress in transistor applications and performance.	A. E. Takacs
Tomorrow's Transistors Depend on Better Semiconductor Bulk Properties	Electronic Design July 9, 1958	The need for a higher degree of crystal perfection is leading to improved techniques.	A D. Kurtz C. Gravel
A Method for Sharpening the Output Waveform of Junction Transistor Multivibrator Circuits	Electronic Engineering (Brit.) June 1958	Method reduces recharging time of coupling capacitors.	A. E. Jackets
Transistorized I-F Strip Design	Electronic Equipment Engineering June 1958	Design history of a missile-system amplifier illustrating problems and their solutions.	R. E. Murphy R. S. Mautner
Transistor Blocking Oscillator Circuits	Electronic Equipment Engineering June 1958	Wide range of output characteristics achieved through circuit and pulse transformer design.	A. S. Daddaris
Designing Transistor Circuits—Switching Statics	Electronic Equipment Engineering June 1958	Basic switching properties are examined considering only static properties.	R. B. Hurley
Designing Transistor Circuits—Switching Dynamics	Electronic Equipment Engineering July 1958	Dynamic behavior of transistor switches is considered.	R. B. Hurley
A Voltage Variable Capacitor (Part 2)	Electronic Industries July 1958	Applications include FM modulation, resonant slope dielectric amplifier and variable filter.	G. F. Straube
A Practical Approach to Solving Thermistor Problems	Electronic Industries July 1958	Background discussion and specific design problems worked out.	R. S. Goodyear
The Germanium Photo-Tetrode	Electronic Industries July 1958	Characteristics, tests, and applications of a photo-transistor as a tetrode equivalent.	F. A. Stahl G. Dermit
Bilateral Conductivity in Power Transistors	Electronic Industries July 1958	Characteristics of bilateral conductivity and application to horizontal deflection in TV.	I. G. Maloff
Manufacture of Silicon Transistors	Electronic and Radio Eng. (Brit.) June 1958	An assessment of the present state of their technology.	J. T. Kendall
Thermistors	Electronic and Radio Eng. (Brit.) June 1958	A review of their properties and applications.	K. R. Patrick
Transistor Power Supply has Overload Protection	Electronics June 20, 1958	Circuit provides instantaneous response when supply is shorted or regulator transistor is overloaded.	H. D. Ervin
Solid State Photocell Sees Through Haze	Electronics June 20, 1958	Radioactive atomic source, detector, and transistor amplifier operates control element.	P. Weisman S. L. Ruby

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
New Intermetallics Offer Wide Infrared Response	Electronics July 4, 1958	Discussion of properties and characteristics of indium-antimonide detector cells.	S. J. Nicolosi L. H. Devaux A. J. Strauss
Diode Cuts Transistor Cutoff-Current Drift	Electronics July 18, 1958	Thermal variations in CE amphiflers can be compensated by diode across base-emitter junction	H. H. Hoge
Half-Adders Drive Simultaneous Computer	Electronics July 18, 1958	Article describes computation method, operation, multiplier gate and operating characteristics	F. B. Maynard
How Transistor Circuits Protect Atomic Reactors	Electronics July 18, 1958	Description of system includes block diagram, and circuit operation.	E. J. Wade D. S. Davidson
The Transverse Magnetoresistance Effect in Indium Antimonide	Journal of Electronics and Control (British) March 1958	Measurements have been made on a wide range of nearly single crystal specimens at different temperatures.	C. H. Champness
A High Frequency Germanium Drift Transistor by Post Alloy Diffusion	Journal of Electronics and Control (British) March 1958	A new technique of solid state diffusion, whereby two or more impurities of different conductivity type are alloyed into *n*-type germanium to produce an alloyed *p-n* junction.	J. S. Lamming
Majority Carrier Lifetime in Copper Doped Germanium at 20°K	Journal of Electronics and Control (British) April 1958	The time constant for recombination of a hole has been derived from experimental data based on (a) the photoconductive sensitivity and (b) the semiconductor shot noise.	D. A. H. Brown
On the Variation of Transistor Small-Signal Parameters with Emitter Current and Collector Voltage	Journal of Electronics and Control (British) April 1958	This variation has been investigated theoretically and the results have been compared with those of a parallel experimental investigation.	N. I. Meyer
The Effect of Electric Fields on Scintillations in Crystalline Zinc Sulphide	Journal of Electronics and Control (British) May 1958	The effects of both static and *a-c* electric fields on scintillations produced by alpha particles in zinc sulphide have been examined.	G. F. Alfey K. N. R. Taylor
IRE Standards on Solid-State Devices: Methods of Testing Point-Contact Transistors for Large-Signal Applications 1958	Proceedings of the IRE May '58	This standard recommends and describes methods of measurement of the important characteristics of transistors in large-signal applications.	
New Applications of Impedance Networks as Analog Computers for Electronic Space Charge and for Semiconductor Diffusion Problems	Proceedings of the IRE May '58	Starting from a general partial differentiation equation of the second order, an equivalent equation with finite differences is discussed.	G. Cremosnik A. Frei M. J. O. Strutt
Transient Response of Drift Transistors	Proceedings of the IRE '58	The short-circuit transient response of a drift transistor is found for a step of input current.	R. C. Johnston
Multiterminal P-N-P-N Switches	Proceedings of the IRE June 1958	Operation depends in part upon electric field transport of minority carriers.	R. W. Aldrich N. Holonyak
The Application of Transistors to Computers	Proceedings of the IRE June 1958	Some of the prevalent circuit theories now in use are discussed.	R. A. Henle J. L. Walsh
Application of Transistors in Communications Equipment	Proceedings of the IRE June 1958	Circuit techniques which are useful in the application of transistors to communications.	D. D. Holmes
The Status of Transistor Research in Compound Semiconductors	Proceedings of the IRE June 1958	Gallium Arsenide and indium phosphide are promising materials.	D. A. Jenny
The Preparation of Semiconductor Devices by Lapping and Diffusion Techniques	Proceedings of the IRE June 1958	Lapping instead of etching is used to shape units made from large semiconductor wafers.	H. Nelson
The Effects of Neutron Irradiation on Germanium and Silicon	Proceedings of the IRE June 1958	An expression relating grounded emitter current gain to accumulated neutron dose is derived.	G. C. Messenger J. P. Spratt
A Five-Watt Ten-Megacycle Transistor	Proceedings of the IRE June 1958	The design, static characteristics, equivalent circuit, and performance data for the device are given.	J. T. Nelson J. E. Iwersen F. Kewell
Properties of Silicon and Germanium: II	Proceedings of the IRE June 1958	Up-to-date information on the fundamental properties of germanium and silicon.	E. M. Conwell
A Design Basis for Junction Transistor Oscillator Circuits	Proceedings of the IRE June 1958	Based on the dynamic admittance presented to the load at the oscillation frequency.	D. F. Page
Transistor Monostable Multivibrators for Pulse Generation	Proceedings of the IRE June 1958	Pulse generators utilizing clamped transistors as active non-linear elements.	J. J. Suran
Measurement of Internal Temperature Rise of Transistors	Proceedings of the IRE June 1958	Uses variation of alpha with T° and static characteristics at constant T°.	J. T. Nelson J. E. Iwersen

TITLE	PUBLICATION	CONDENSED SUMMARY	AUTHOR
Lumped Models of Transistors and Diodes	Proceedings of the IRE June 1958	Properties of transistors and diodes may be approximated over a wide range of conditions.	J. G. Linvill
Advances in the Understanding of the P-N Junction Triode	Proceedings of the IRE June 1958	Topics include small-signal parameters and switching characteristics.	R. L. Pritchard
Narrow Base Germanium Photodiodes	Proceedings of the IRE June 1958	Analysis of operation as reverse-biased and photovoltaic detectors.	D. E. Sawyer R. H. Rediker
New Concepts in Microwave Mixer Diodes	Proceedings of the IRE June 1958	New processes, new semiconductor materials such as gallium arsenide, and cooling.	G. C. Messenger
The Technological Impact of Transistors	Proceedings of the IRE June 1958	Major milestones and problems during the development of the art.	J. A. Morton W. J. Pietenpol
The Potential of Semiconductor Diodes in High-Frequency Communications	Proceedings of the IRE June 1958	Possible uses for graded *p-n* junction, point-contact, and *p-i-n* diodes.	A. Uhlir Jr.
Analog Solution of Space-Charge Regions in Semiconductors	Proceedings of the IRE June 1958	Application to solution of Poisson's equation for complex geometries.	L. J. Giacoletto
The Evolution of the Theory for the Voltage-Current Characteristic of P-N Junctions	Proceedings of the IRE June 1958	At high current densities the junctions depart from the ideal low-level rectifier law because of effects associated with majority carrier modulation.	J. L. Moll
Outdiffusion as a Technique for the Production of Diodes and Transistors	Proceedings of the IRE June 1958	Usefulness depends on how easily impurities can be evaporated from the crystal surface.	J. Halpern R. H. Rediker
Irradiation of P-N Junctions with Gamma Rays: A Method for Measuring Diffusion Lengths	Proceedings of the IRE June 1958	A derivation of the generation rate g of an irradiated junction. If the short-circuit current and g are known the diffusion length can be calculated.	R. Gremmelmaier
The Blocking Capability of Alloyed Silicon Power Transistors	Proceedings of the IRE June 1958	Considerations of pure breakdown, simultaneous breakdown and punch-through, and pure punch-through.	R. Emeis A. Herlet
The Electrical Characteristics of Silicon P-N-P-N triodes	Proceedings of the IRE June 1958	Base current is found to decrease the breakover (peak) voltage and to decrease the turn-off current.	I. M. Mackintosh
The Effective Emitter Area of Power Transistors	Proceedings of the IRE June 1958	Only the border region in a width of one diffusion length is effective.	R. Emeis A. Herlet E. Spenke
Noise in Semiconductors and Photoconductors	Proceedings of the IRE June 1958	Includes generation-recombination, modulation noise, and l-f noise.	K. M. van Vliet
Recombination in Semiconductors	Proceedings of the IRE June 1958	Recombination at surfaces is described in terms of a model.	G. Bemski
Junction Transistor Short Circuit Current Gain and Phase Determination	Proceedings of the IRE June 1958	It is shown that the complete common-base and common-emitter current-gain magnitude and frequency characteristics can be determined from three amplitude measurements.	D. E. Thomas J. L. Moll
Technology of Micro-Alloy Diffused Transistors	Proceedings of the IRE June 1958	Control-of-design variables and new circuit and measurement techniques.	C. G. Thornton J. B. Angell
Construction and Electrical Properties of a Germanium Alloy-Diffused Transistor	Proceedings of the IRE June 1958	The alloy-diffusion method of constructing high-frequency transistors is described. A T equivalent circuit valid up to 25 *mc* is presented.	P. J. W. Jochems O. W. Memelink L. J. Tummers
Power Transistors	Proceedings of the IRE June 1958	Design theory in terms of phenomena important at high current densities and voltages.	M. A. Clark
Noise in Junction Transistors	Proceedings of the IRE June 1958	Theory of the shot effect and Fongers theory of flicker noise.	A. van der Ziel
Two-Dimensional Current Flow in Junction Transistors at High Frequencies	Proceedings of the IRE June 1958	At high frequencies the distributed nature of the base region must be accounted for, with complex impedance replacing ohmic resistance.	B. L. Pritchard
Measurement of Transitor Thermal Resistance	Proceedings of the IRE June 1958	A two step process of determining the over-all junction-to-ambient thermal resistance.	B. Reich
Formation of Junction Structures By Solid-State Diffusion	Proceedings of the IRE June 1958	Variations of the diffusion coefficient, diffusion techniques; evaluating diffused layers.	F. M. Smits
Electrons, Holes, and Traps	Proceedings of the IRE June 1958	The results of the Shockley-Read recombination theory are derived and interpreted.	Wm. Shockley
Review of Other Semiconductor Devices	Proceedings of the IRE June 1958	Classification of semiconductor devices according to external and internal influences, acting upon them.	S. J. Angello
Germanium and Silicon Rectifiers	Proceedings of the IRE June 1958	Discussion of volt-ampere characteristics, methods of fabrication, and applications.	H. W. Henkels

PATENT REVIEW*

Of Semiconductor Devices, Fabrication Techniques and Processes, and Circuits and Applications May 16, 1950 to Sept. 25, 1951

Compiled by SIDNEY MARSHALL

The abstracts appearing in this issue cover the inventions relevant to semiconductors from May 16, 1950 to September 25, 1951. Additional items for the 1948 and 1949 compilations, which appeared in the previous issue, are also included. In subsequent issues, patents issued from September 1951 to date will be presented in a similar manner. After bringing these abstracts up to date, PATENT REVIEW will appear every three months, the treatment given to each item being more detailed.

Addenda for 1948, 1949

January 13, 1948
2,434,286 Method of Forming A Point at the End of a Wire;—W. G. Pfann; Assignee: Bell Telephone Laboratories; The method of shaping an electrical contact wire by electrolytic action thereon while said wire has one end immersed in an aqueous solution of potassium hydroxide.

March 9, 1948
2,437,269 Translating Device and Method of Making It;—R. S. Ohl; Assignee: Bell Telephone Laboratories; A point-contact ultra-high frequency electric wave translator composed of an impurity containing silicon body having a high impedance surface layer.

March 23, 1948
2,438,110 Electrical Translating Materials and Devices and Method of Making Them;—W. H. Brattain; Assignee: Bell Telephone Laboratories; A point-contact translating device comprising a metallic base having a layer of silicon thereon, said layer containing an alloy of silicon and lead.

April 6, 1948
2,438,892 Electrical Translating Materials and Devices and Methods of Making Them;—J. A. Becker; Assignee: Bell Telephone Laboratories; A microwave translating element comprising a base of a metal of the group consiting of tantalum, platinum, tungsten and molybdenum having a layer of silicon deposited and fused thereon.

2,438,893 Translating Device;—C. A. Bieling; Assignee: Bell Telephone Laboratories; A device comprising an insulating housing and a plurality of point-contact translating units mounted within said housing.

May 18, 1948
2,441,590 Translating Device;—R. S. Ohl; Assignee: Bell Telephone Laboratories; In a translating device, a hollow metal cylinder, a metallic base member therein, a rectifying element mounted on said base member, a contact wire engaging said element, and an electrical terminal for said contact wire.

2,441,603 Electrical Translating Materials and Method of Making Them;—K. H. Storks, G. K. Teal; Assignee: Bell Telephone Laboratories; A method of preparing a translating element by treating a folded metallic strip in a reaction chamber filled with a vapor of a silicon compound.

June 15, 1948
2,443,542 Light-Sensitive Electric Device Including Silicon;—R. S. Ohl; Assignee: Bell Telephone Laboratories: A photo-EMF cell comprising a body of solidified fused silicon, said body being cut from an ingot having a striated zone.

February 22, 1949
2,462,218 Electrical Translator and Method of Making It;—K. M. Olsen; Assignee: Bell Telephone Laboratories; A method that consists of forming a silicon body having a small percentage of impurities therein and heat treating said body to form an impurity-free layer.

July 19, 1949
2,476,323 Multielectrode Modulator;—A. J. Rack; Assignee: Bell Telephone Laboratories: A modulator which comprises a semiconductive body, an absorber electrode making rectifying contact with said body; a control electrode, and two electrodes so biased as to act as emitter electrodes.

November 1, 1949
2,486,776 Self Biased Electric Translating Device;—H. L. Barney; Assignee: Bell Telephone Laboratories: A semiconductor signal translating device which is characterized by reverse direction collector current which is variable under control of a signal applied to the control electrode.

[CONTINUED FROM LAST ISSUE]

May 16, 1950
2,507,782 Rectifiers;—M. Goodman; Assignee: Radio Receptor Company Inc.; The barrier layer of a selenium cell is formed by treating the selenium with acid of an element from group V or group VI.

May 30, 1950
2,509,342 Electrical Rectifier Construction;—L. K. Hedding, S. H. Zierdt; Assignee: Union Switch and Signal Company; An assembly arrangement for rectifier plates.
2,509,864 Electromagnetic Amplifier;—S. E. Hedstrom; Assignee: Allmanna Svenska Elektriska Aktiebologet (A Swedish Corporation); An electromagnetic amplifier utilizing rectifier circuits.
2,509,865 Frequency Compensated Saturable Reactor System;—S. E. Hedstrom, R. Svensson; Assignee: Allmanna Svenska Elektriska Aktiebologet (A Swedish Corporation); An electric regulator having as one of its circuits a rectifier network.

June 6, 1950
2,510,075 Modulator of the Dry Type;—A. C. Clavier, M. Denis; Assignee: International Standard Electric Corp.; A carrier current signaling system comprising a plurality of unidirectional conducting elements.
2,510,092 Rectifier;—C. A. Escoffery. W. H. Hawk; Assignee: Federal Telephone and Radio Corp.; A selenium rectifier unit comprising at least two coaxially arranged rectifier elements.
2,510,322 Selenium Rectifier;—R. E. Shearer; Assignee: The Union Switch and Signal Company; The formation of the rectifier cell by maintaining the cell at a predetermined temperature, and applying a reverse voltage through a ballast resistance.
2,510,361 Method of Producing Selenium Rectifiers;—N. H. Addink; Assignee: The Hartford National Bank and Trust Company; A method that involves the heating of a selenium-dissolving organic liquid to its boiling point in order to produce a dissolved resinous material.

July 11, 1950
2,514,879 Alloys and Rectifiers Made Thereof;—K. Lark-Horovits, R. M. Whaley; Assignee: Purdue Research Foundation; A germanium point-contact device.

July 25, 1950
2,516,344 Rectifier;—D. W. Ross; Assignee: United States of America (Navy Dept.); A rectifier assembly completely sealed and encased in a plastic material.
2,517,602 Metal Contact Rectifier and Photoelectric Cell;—E. A. Richards, L. J. Ellison; Assignee: International Standard Electric Corp.; An improved sele-

*Source: Official Gazette, United States Patent Office.

nium cell in which a flat insulator is placed between the base plate and the counter-electrode in the regions where pressure is applied.
2,517,960 Self-Biased Solid State Amplifier;—H. L. Barney, R. C. Mathes; Assignee: Bell Telephone Laboratories; The combination with an amplifier comprising a semiconductive body and at least three metallic electrodes making direct electrical contact with said body.

August 15, 1950
2,518,953 Means for Generating Low-Frequency Electrical Oscillations;—H. M. Sorensen; Assignee; Allmanna Svenska Elektriska Aktiebologet; Means for generating low frequency electrical oscillations comprising among other things rectifying elements.

September 12, 1950
2,521,522 Rectifier Measuring Circuit;—R. Keitky; Assignee: General Electric Company; Rectifier measuring apparatus comprising at least four parallel connected circuits some of which contain barrier layer rectifiers, and some of which contain metering apparatus.

September 12, 1950
2,522,395 Electric Wave Transmission;—R. S. Ohl; Assignee: Bell Telephone Laboratories; An oscillation transmission system comprising a pair of conductors divided into sections of relatively large attenuation for oscillations of the frequency to be transmitted.

September 19, 1950
2,522,521 Thermal Transistor Microphone;—W. E. Kock; Assignee: Bell Telephone Laboratories; A microphone which comprises a block of semiconductor material, a point contact electrode, and a low resistance contact electrode.

October 3, 1950
2,524,033 Three-Electrode Circuit Element Utilizing Semiconductive Material;—J. Bardeen; Assignee: Bell Telephone Laboratories; A semiconducting body and point-contact electrode and a source of voltage for biasing the electrode in a reverse direction.
2,524,034 Three-Electrode Circuit Element Utilizing Semiconductor Materials;—W. H. Brattain, R. B. Gibney; Assignee: Bell Telephone Laboratories; A circuit element comprised of a layer of semiconductive material, means for passing a current longitudinally within said layer, and an electrolyte in contact with a face of said layer.
2,524,035 Three-Electrode Circuit Element Utilizing Semiconductive Materials;—J. Bardeen, W. H. Brattain; Assignee: Bell Telephone Laboratories; A circuit element comprising a body of semiconductor material, one portion of which is of one conductivity type, and another portion of which is of a different conductivity type.
2,524,270 Selenium Rectifier;—L. S. Pelfrey; Assignee: Sylvania Electric Products, Inc.; The method of making a selenium rectifier by nickel plating a metal, hydrogen-firing the coating, coating the nickel with selenium which in turn is coated with cadmium.

November 14, 1950
2,530,110 Non-Linear Circuit Device Utilizing Germanium;—J. R. Woodyard; Assignee: The Sperry Corporation; A rectifier comprising a plate of germanium-phosphorus alloy and a point of hard conducting material in contact with the surface of the plate.

November 21, 1950
2,530,745 Transistor Microphone With Conductive Grains;—R. L. Wallace; Assignee: Bell Telephone Laboratories; A device having a semiconductive body with a two-part surface, means for point contacts with both parts, and a vibration responsive device.
2,531,076 Bistable Semiconductor Multivibrator Circuit;—R P. Moore; Assignee: Radio Corporation of America; A bistable multivibrator circuit comprising two semiconductor devices, each having a base electrode, an emitter electrode, and a collector electrode.

November 28, 1950
2,531,402 Manufacture of Dry Rectifiers;—C. L. Coper, L. J. Ellison; Assignee: International Standard Electric Corp.; Vacuum apparatus for use in the mass production of selenium dry disk rectifiers.
2,531,415 Rectifier;—C. A. Escoffery; Assignee: Federal Telephone and Radio Corp.; A selenium rectifier of rod shaped construction.
2,533,225 Regulated Rectifier;—L. P. Cronvall, G. Winkler; Assignee: International Standard Electric Corp.; A simplified circuit arrangement for securing a harmonic-free unidirectional current output.

December, 26, 1950
2,535,303 Electronic Switch;—W. D. Lewis; Assignee: Bell Telephone Laboratories; Switching means comprising a pair of rectifiers connected in series between a source and a load, a plurality of similar rectifiers each having one electrode connected to a point between the first pair a resistance in parallel with each of said rectifiers, and a voltage source connected to each of the devices.

January 9, 1951
2,537,255 Light-Sensitive Electric Device;—W. H. Brattain; Assignee: Bell Telephone Laboratories; The device described is composed of a body of solidified fused purified silicon covered by a thin film of amorphous silicon, and electrical contacts to the silicon body and the silicon film.
2,537,256 Light-Sensitive Electric Device;—W. H. Brattain; Assignee: Bell Telephone Laboratories; A device composed of a body of cuprous oxide, a thin film of silicon thereon, and a light-transmitting film of tungsten covering the silicon.
2,537,257 Light-Sensitive Electric Device;—W. H. Brattain; Assignee: Bell Telephone Laboratories; A device composed of a body of cooled fused purified silicon powder covered by a layer of silicon or a silicon oxygen compound.

January 16, 1951
2,537,961 Rectifier;—W. F. Bonner; Assignee: Federal Telephone and Radio Corp.; A rectifier assembly comprising an envelope having a curved internal surface and a plurality of rectifying elements of the semi-conductor type.
2,538,495 Metallic Container Sealing Method; J. F. Barry; Assignee: Bell Telephone Laboratories; The method of hermetically sealing a metallic casing enclosing a crystal unit.
2,538,593 Semiconductor Amplifier Construction; G. M. Rose; Assignee: Radio Corporation of America; A device comprising a semiconductive body, two resilient filamentary members, and means for causing these filaments to contact the semiconductor at a predetermined position and with a predetermined pressure.

January 30, 1951
2,539,894 Dry Surface Contact Rectifier Assembly;— R. C. Cubitt; Assignee: The Union Switch and Signal Co.; A rectifier assembly in which a rectifier is arranged within a tube of insulating material.

February 6, 1951
2,540,490 Electron Device With a Semiconductive Target;—E. S. Rittner Assignee: Philips Laboratories Inc.; An electron discharge tube with a target electrode consisting of a pair of spaced terminal electrodes and an active element of the germanium silicon group placed between them.

February 13, 1951
2,541,322 Control of Impedance of Semiconductor Amplifier Circuits;—H. L. Barney; Assignee: Bell Telephone Laboratories: A transistor amplifier having adjustable input and output impedances.
2,541,832 Electric Current Rectifier;— F. R. Quinn; Assignee: General Electric Company; A rectifier element comprising a molybdenum electrode and a second electrode made of molybdenum sulfide and a sulfide of the group II metals.

February 20, 1951
2,542,115 Photosensitive Device;— F. C. Brown; Assignee: None. The device has a photosensitive element selected from the germanium silicon group, said element having an exposure area of 0.1 to 1.0 square millimeters.
2,542,727 Etching Processes and Solutions;—H. C. Theuerer; Assignee: Bell Telephone Laboratories; The process of preparing the surface of a germanium body which comprises etching said surface in an aqueous solution of hydrogen peroxide and hydrogen fluoride.

February 27, 1951
2,543,048 Photocell;— H. J. Nachod; Assignee: Federal Telephone and Radio Corp.; A photocell unit comprised of a disk type base plate electrode, a layer of light-responsive semi-conductive material, and a translucent conductive front electrode.
2,543,071 Seed for Crystal Growing;— S. I. Slawson; Assignee: None; A capped seed crystal for the growing of crystal bars comprising a polyhedral block of material to be crystallized.
2,543,678 Method of Producing Rectifier Elements;— G. Tumolo; Assignee: Radio Receptor Co. Inc.; A method of manufacturing a plurality of selenium rectifiers each of which incorporates as a base a section from a metal plate which is later subdivided.

April 3, 1951
2,547,386 Current Storage Device Utilizing Semiconductor;— F. Gray; Assignee: Bell Telephone Laboratories; The resistance of the metallic electrode that makes contact with the semiconductor is sensitive to the presence of electric charge in its vicinity.
2,547,406 Method and Means for Controlling the Resistance of Oxidic Semiconductors;— F. J. Morin; Assignee: Bell Telephone Laboratories; A thermally responsive semiconductor having a high negative temperature coefficient of resistance comprised of a mixture of manganese, nickel, and beryllium oxides.

April 17, 1951
2,549,550 Vibration-Operated Transistor;— R. L. Wallace; Assignee: Bell Telephone Laboratories; A device comprising

a body of semiconductive material and a carbon tipped input electrode making point contact with the semiconductor.

April 24, 1951

2,550,492 Hall Effect Alternating Current Measuring Apparatus;— N. P. Millar; Assignee: General Electric Co.; In a measuring system apparatus is employed for obtaining direct and alternating currents proportional to the watts and volt amperes of an alternating current circuit.

2,550,518 Control of Impedance of Semiconductor Amplifier Circuits;— H. L. Barney; Assignee: Bell Telephone Laboratories; An amplifier adapted to be connected in cascade between a low impedance source and a low impedance load.

2,551,048 Method of Making Selenium Coated Elements;— C. E. Peters, D. W. Rau; Assignee: Vickers Inc.; The method of making a selenium coated supporting element with a smooth, adherent, uniform-thickness nuclei-containing coating of selenium thereon.

May 15, 1950

2,552,626 Silicon-Germanium Resistor and Method of Making It.; J. R. Fisher, G. K. Teal; Assignee: Bell Telephone Laboratories; A resistor comprising a ceramic support, a thin film on said support of a material consisting of a mixture of silicon and germanium, and a spaced electrical connecting means secured to said film.

2,552,952 Magnetic Amplifier;— P. Gachet, P. J. de Montgemier; Assignee; Yves Rocard (French Corporation); A magnetic amplifier utilizing four rectifying units and two saturable magnetic cores.

2,553,420 Radiation Detector;— R. H. McFee; Assignee: Photoswitch, Inc.; A photoconductive cell comprising: three spaced electrodes, a film of semiconductive radiation-sensitive material, and a radiation shield.

2,553,490 Magnetic Control of Semiconductor Currents;—R. L. Wallace; Assignee: Bell Telephone Laboratories; In a body of semiconductive material, means for establishing a current of pairs of mobile charges, and a controlled magnetic field for directing the current to any desired collecting electrode.

2,533,491 Acoustic Transducer Utilizing Semiconductors;—W. Shockley; Assignee: Bell Telephone Laboratories; An electromechanical transducer comprising a body of semiconductive material and means of controlling its current carriers, electric field, magnetic field, and mechanical vibrations.

May 22, 1951

2,554,237 Rectifier;—W. E. Blackburn; Assignee: Westinghouse Electric Corp.; A rectifier, the selenium layer of which is coated with a film compounded from selenium and cadmium, zinc, or magnesium.

May 29, 1951

2,554,979 Element of Asymmetric Conductivity of Selenium—R. Doucot; Assignee: Compagnie des Freins et Signaux Westinghouse; A contact member for making contact under pressure with the counter-electrode layer.

2,555,001 Bonded Article and Method of Bonding;—R. S. Ohl; Assignee: Bell Telephone Laboratories; A current regulating device comprising a silicon or germanium wafer and a base to which said wafer is bonded, the bonding agent consisting of an element from group IVa.

2,555,247 Semiconductive Cell;—O. Saslaw; Assignee: Vickers Inc.; A method for making a selenium cell involving the spray-formation of a low melt metal counter-electrode.

June 12, 1951

2,556,286 Oscillation Generator;—L. A. Meacham; Assignee: Bell Telephone Laboratories; A transistor device including means for providing collector output power feedback to the emitter, a reactive frequency-determining circuit, and a low impedance load between the emitter and the base.

2,556,296 High-Frequency Transistor Oscillator;—A. J. Rack; Assignee: Bell Telephone Laboratories; A generator of oscillations of frequencies at which mobile charge transit time effects play a controlling part.

2,556,711 Method of Producing Rectifiers and Rectifier Material;—G. K. Teal; Assignee: Bell Telephone Laboratories; The method involves depositing a body of germanium having a trace of impurities from the antimony-arsenic group

2,556,991 Light-Sensitive Electric Device; —G. K. Teal; Assignee: Bell Telephone Laboratories; A method of producing a photoconductive layer by treating a ceramic body with vapors of a chloride of silicon, boron, or germanium.

2,558,086 Reactor-Controlled Adjustable-Speed Drive;—L. W. Herchenroeder Assignee: Westinghouse Electric Corporation; An adjustable-speed drive comprising a D. C. motor, an armature circuit, means for energizing said armature, a rectifier circuit and a saturable reactance device.

July 17, 1951

2,560,579 Semiconductor Amplifier;—W. E. Kock, R. L. Wallace; Assignee: Bell Telephone Labs; A device comprising a body of semiconductive material having a thin central portion and a thick portion surrounding said central portion, a conductive housing supporting the body, and means for making contact to opposite sides of said thin central portion.

2,560,594 Semiconductor Translator and Method of Making It;—G. L. Pearson; Assignee: Bell Telephone Laboratories; The width of a thinned central portion of a semiconductive body is reduced to the dimensions of the thickness to provide a filement and a portion of greater cross section.

2,560,606 Photoresistive Translating Device;—J. N. Shive; Assignee: Bell Telephone Laboratories; A device having a point contact electrode at a point of reduced thickness and a means for directing radiation against the surface portion opposite the thinned section.

2,560,792 Electrolytic Surface Treatment of Germanium;—R. B. Gibney; Assignee: Bell Telephone Laboratories; The treatment of a block of high back-voltage n-type germanium to form a surface layer of p-type germanium separated from the block by a high resistance barrier.

2,561,109 Semiconductor Device;—L. J. Giacoletto; Assignee: Radio Corporation of America; A semiconductor device, suitable as an amplifier or an oscillator, and providing an improved method of achieving a plurality of small area contacts.

2,561,123 Multicontact Semiconductor Devices;—J. Kurshan; Assignee: Radio Corporation of America; A wire mesh and means for connecting it to the semiconductive body on which it rests provides a plurality of small area contacts between the mesh conductors and the body.

July 24, 1951

2,561,411 Semiconductor Signal Translating Device;—W. G. Pfann; Assignee: Bell Telephone Laboratories; A three terminal device having a zone of material of one conductivity type imbedded in the surface of a body of semiconductor of the opposite conductivity type.

August 7, 1951

2,563,406 Electronic Commutator;—E. A. Goldberg; Assignee: Radio Corporation of America; An electronic commutator comprising a bridge circuit including rectifiers, all connected to permit current flow therethrough in the same direction when suitably excited.

2,563,503 Transistor;—R. L. Wallace; Assignee: Bell Telephone Laboratories; A three terminal device with the emitter and base electrodes in close proximity.

2,563,613 Translating Means for Ultra-Short Wavelength Energy;—R. S. Ohl; Assignee: Bell Telephone Laboratories; A device comprising a hollow outer conductor, an insulator body having an inner conductor extending therethrough, a conductive body spaced in relation to the insulator so as to form a cavity and a point-contact crystal device within said cavity.

August 14, 1951

2,563,504 Semiconductor Translating Device;—W. G. Pfann; Assignee: Bell Telephone Laboratories; A signal translating device having two meeting surfaces, a base connection on one of the surfaces, and an emitter connection in proximity to the junction.

August 21, 1951

2,565,338 Germanium Crystals;—S. F. Amico; Assignee: Sylvania Electric Products; The method of making semiconductive germanium including mixing pulverized germanium and its oxide, melting, and cooling the melt.

August 28, 1951

2,565,483 Process for Manufacturing Selenium Cells;—D. L. Driver; Assignee: International Standard Electric Corp.; An improved process in which a base plate is coated with selenium by spraying molten selenium onto the plate under gas pressure.

2,565,497 Circuit, Including Negative Resistance Device;—J. W. Harling; Assignee: International Standard Electric Corp.; An electric trigger circuit containing a germanium crystal rectifier and means for biasing the point contact electrode negatively with respect to the base.

September 18, 1951

2,567,970 Semiconductor Comprising Silicon and Method of Making It;—J. H. Scaff, H. C. Thauerer; Assignee: Bell Tel. Labs.; A semiconducting body having both n-type and p-type conductivity portions and an intermediate barrier layer of photo-voltaic material.

September 25, 1951

2,568,780 Rectifier Manufacturing Process and Products obtained thereby;—A. von Hippel, M. C. Bloom; Assignee: Federal Telephone and Radio Corp.; The depositing of selenium on a cathode during the electrolysis of a concentrated solution of selenium dioxide.

[CONTINUED IN NEXT ISSUE]

New Products

Pressure-To-Frequency Device

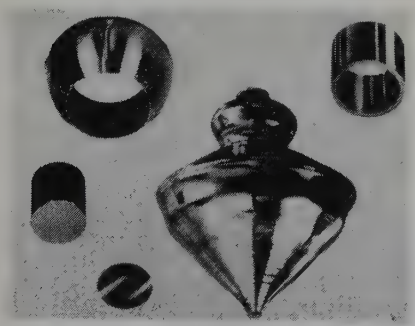
Solid State Electronics Co. announces the availability of its Osciducer an ultra miniature pressure-to-frequency converter which provides a new simplified approach to missile, space vehicle, aircraft, and industrial telemetering. A temperature stabilized silicon transistor oscillator has been welded to a variable inductance diaphragm-type pressure transducer to provide a complete in-line instrumenta-

tion module for the remote measurement of pressure. Commonly used interwiring between oscillator and transducer has been eliminated. For convenience, the units may also be mounted separtely. The Osciducer requires but three connections for operation: 28 volts *d-c* at 2 *ma*, ground and the output. A silicon transistor emitter follower low-impedance output is provided to isolate the oscillator from external loading.

Circle 155 on Reader Service Card

Six Inch Boules

U.S. Semcor reveals a new-type furnace that grows silicon ingots up to six inches diameter. The process develops polycrystalline or monocrystalline densified silicon which can be optically polished for such uses as infrared prisms, tubes, lenses, correcting plates, recticles



and photocell windows, and may be used as nose dome "windows" for long-range radiation detection, point-to-point communications, industrial process control, chemical and physical analysis, solar converters, weather monitoring and forecasting.

Circle 183 on Reader Service Card

Miniature Photocells

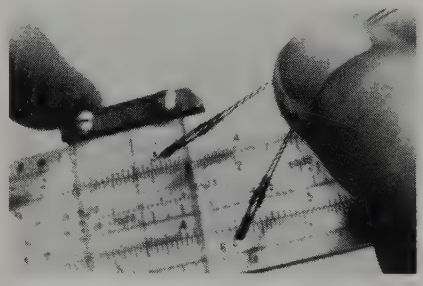
The formulation of a line of thirteen miniature photoconductive cells, responsive as a group over the entire range of the visible spectrum and somewhat be-

yond, has been announced here by the Clairex Corp. The photoconductive elements consist of two types—polycrystalline cadmium sulfide and cadmium selenide. Power dissipation is 50 milliwatts for the plastic units and 75 for the glass types, with ambient temperature ranging from −50° to +75°C. A ten page brochure, complete with photographs, charts and tables, outlining technical details and a list of applications is available.

Circle 174 on Reader Service Card

New Solid State Probe

Featuring a positive temperature coefficient that results in a constant rate of change on the order of 0.7%/°C along a retraceable curve, the new sensing device (Sensistor) is made available by



Texas Instruments, Inc. This device is encased in a glass package only 0.078 inch in diameter and 0.500 inch in length. This small size coupled with such a large temperature coefficient of resistance enables the Sensistor probe to indicate quickly and accurately temperature changes by measuring the resistance in a mass and recording this resistance as a temperature indication.

Circle 186 on Reader Service Card

Thermal Relay

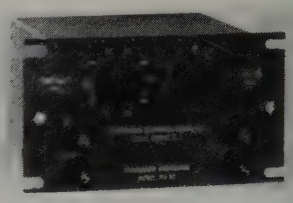
A new thermal relay, designed for the demanding conditions of missile operation, is being offered to the industry by Hughes Products, Hughes Aircraft Company. Relay is a one-time operating, single-pole thermal device with a faultless hermetic seal. Small size, positive operation, and convenience of location adjacent to desired components are advantages listed for the new product. Three steps occur within the relay when an electric signal is triggered: 1. Firing effects the release of constrained contact. 2. Contact closes upon a fixed contact point. 3. Switch circuit becomes permanently closed.

Circle 178 on Reader Service Card

Transistorized Relay

Electronic Research Associates, Inc., announces the availability of their new transistorized relay Model RV30 which provides over-voltage and short-circuit current protection for transistorized power supplies and connected equipment. Specifications for the Model RV30 include an over-voltage adjustment range of 5-50 V *d-c*, over-current adjustment range of 100 *ma*-1 ampere. Pass current is 0.1 ampere. Voltage drop within the unit is less than 0.4 V. Response time of the unit is approximately 25 micro-seconds. The *a-c* turn-off rating is 115 V *a-c*, 5 amperes.

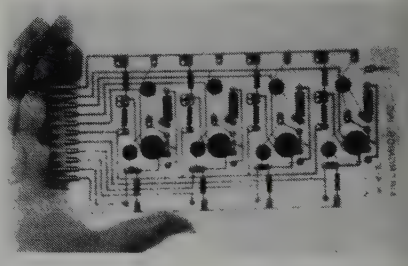
Circle 176 on Reader Service Card



Transistorized Pulser

The new Airtronics, Incorporated DK 402 MOD I power pulser is a fully transistorized, high current magnetic memory matrix driver with current pulses up to 400 milliamperes. The printed circuit card as shown contains four separate two-transistor blocking oscillator pulsers. The pulser "on" time is determined by the controlled rate of flux-switching in a square loop magnetic core. Each of the four pulsers is capable of switching 400 milliamperes for a maximum period of 10 micro-seconds at a 20 *kc* repetition rate at 25° C. ambient temperature.

Circle 158 on Reader Service Card



Shift Register For Transistor Driver

The DK 101-T is a two-core-per-bit shift register designed for use with a transistor driver. This new series of shift resistors features a nominal drive current which has been raised from 100 milliamperes to 300 milliamperes to match transistor capabilities. The resulting 3 to 1 reduction in reactive voltage developed across the drive winding permits three times as many units to be driven in a series string.

Circle 152 on Reader Service Card

New Hydrofluoric Acid Bottle

Mallinckrodt Chemical Works introduces a new package, a 1-lb hydrofluoric acid bottle made of "Marlex" polyethylene. This new patented container has a special, controlled-delivery closure which permits drop or flow action at any time. As an additional feature all of the label-

(*Continued on page* 56)

Industry News [from page 14]

pounds. Also supplied are the following ultra-high purity form of the constituent materials specially processed for the production of the intermetallic compounds: indium, antimony, arsenic, lead, bismuth, and tellurium. A new semiconductor device from the materials produced is the Halltron, a unit based upon the Hall-Effect. The output characteristics of the Halltron are a function of the product of the input current and the applied magnetic field.

Prices of Fansteel Type 2A Silicon Rectifiers have been reduced approximately 30%, H. Paul Weirich, assistant general manager of Fansteel Metallurgical Corporation's Rectifier-Capacitor Division, announced on Sept. 18, 1958. These lower prices are made possible by technical improvements and production economies, Mr. Weirich stated.

Development of a new method of flameless sealing of glass to glass, providing an inexpensive, high-production means of packaging transistors and rectifiers, has been announced by S. Irving Weiss, president, Trans-Sil Corporation. According to Mr. Weiss, the new Trans-Sil process eliminates the possibility of contamination during the sealing of rectifiers and transistors. It provides a means of consistent hermetic sealing, permitting sealing in a vacuum or an inert atmosphere. In principle, the new Trans-Sil process incorporates the use of a metal ring inserted in powdered glass, and an induction coil which heats the metal ring, causing the glass to flow and thereby creating an airtight seal. Done on a continuous sealing machine, it is estimated that 1,000 units can be sealed each hour.

An international licensing agreement—under which one of Britain's largest electronic companies (The Plessey Company, Ltd.) acquires from General Instrument Corporation the latter's "past, present and future technical know-how" in mass production of silicon rectifiers, plus British and West European manufacturing and sales rights to rectifiers of General Instrument design—was announced recently by General Instrument Board Chairman Martin H. Benedek.

Accurate Specialties Co., Inc. manufacturers of components for semiconductors, announces a new packaging method which considerably increases the shelf life of readily oxidizable metals and alloys. Indium, Lead Antimony, Indium Gallium and other such materials are now packaged in sealed containers with an Argon atmosphere. Glass containers and a vinyl sealer are used. Oxygen does not at any time come in contact with the alloy or metal to be packaged, or the inner parts of the container; nor can the Argon atmosphere escape.

A purified silicon, which offers manufacturers of transistors, diodes, and other semiconductor devices, maximum uniformity of electrical characteristics at substantial savings in cost, has been announced by Sylvania Electric Products Inc. Sylvania P type ultra-high-purity silicon is available in three standard grades based on minmum resistivity—1, 40, and 100 ohm cm. Ingots are 50 mm half round in cross section by 25-30 cm (10-12 inches) in length. Weight is approximately 15 g/cm (40 g/in) which is practically of theoretical density.

Lepel
HIGH FREQUENCY
INDUCTION
HEATING
UNITS
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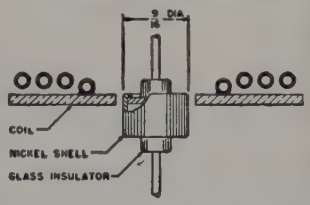
MELTING
The Lepel line of induction heating equipment represents the most advanced thought in the field of electronics as well as the most practical and efficient source of heat yet developed for industrial heating.
If you are interested in induction heating you are invited to send samples of the work with specifications. Our engineers will process and return the completed job with full data and recommendations without any cost or obligations.

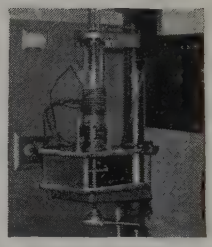
TYPICAL INDUCTION HEATING APPLICATIONS IN THE MANUFACTURE OF TRANSISTORS

SOLDERING TRANSISTOR ASSEMBLIES BY INDUCTION HEATING



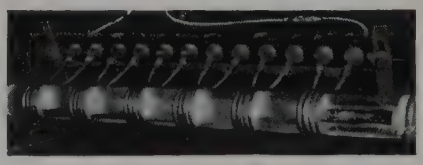
Concentrator-type coil creates high intensity, restricted heating at joint of nickel shell and tinned glass, thus causing solder to flow for permanent seal.

SINGLE CRYSTAL PULLER



General arrangement for pulling single crystals. Induction heating coil is shown surrounding quartz tube containing crucible with molten germanium in suitable atmosphere.

MULTIPLE ZONE REFINING



Induction heating apparatus used in zone refining. The six coils shown provide simultaneous molten zones in the ingot as it passes through the tube containing the protective atmosphere.

Electronic Tube Generators from 1 kw to 100 kw.
Spark Gap Converters from 2 kw to 30 kw.

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Circle 17 on Reader Service Card

Model 850

Tests Transistors Under Circuit Use Conditions

This low cost tester is reliable, easy to use and designed to provide accurate evaluations of a transistor to determine its ability to function under a specific circuit condition. The 850 features a wide range of applied voltages available through use of the voltage control, and is an excellent "breadboard" for building up amplifiers, oscillators and a curve tracer. The panel selector quickly sets choice of circuit-use-condition to detect suitability of a transistor to operate from signal sources of varying impedances. This equipment will check the following parameters under any circuit-use-condition selected by the operator: Collector leakage, C base or C emitter; beta (current) gain; alpha gain; input resistance; output resistance; power gain; linearity.

Use of the 850 will quickly and effectively convey the full understanding of a transistor's function.

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Circle No. 18 on Reader Service Card

NEW PRODUCTS (*from page 54*)

ing on this 1-lb container is printed directly on the container by silk-screen process. This enables the user to see the liquid level at all times. In addition, the blue labeling on the bottle acts as an indicator and turns orange if liquid hydofluoric acid should touch it. After the hydofluoric acid is washed off, the labeling will turn green. It can be restored to its original blue color by applying ammonium hydroxide.

Circle 160 on Reader Service Card

Hall Generator

A new Hall Generator, for use in instrument applications and as an analog computer element, is now available from the Westinghouse Electric Corporation. Used as a circuit element, the Hall Generator is essentially a solid-state multiplying device that provides a voltage output proportional to the product of two electrical quantities: the control current passing through it and the magnetic field perpendicular to its major face. Therefore, it can multiply two electrical quantities if one is expressed as current and the other as a magnetic field. Because of its extremely fast response time, the Hall Generator can also be used to measure the power content of transients.

Circle 156 on Reader Service Card

Tantalum Capacitors

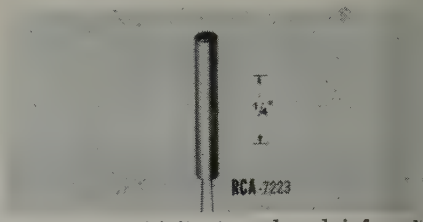
Improved tubular-case sintered-anode tantalum capacitors with complete ratings and performance characteristics are described in Sprague's new Engineering Bulletin 3700B. These Type 109D capaci-

tors are indicated for use in all applications where the original shouldered cup-type designs were used. Superior characteristics are claimed with regard to low temperature, impedance at higher frequencies, and life test duration.

Circle 187 on Reader Service Card

Photojunction Cell

The RCA 7223 is a very tiny photojunction cell of the head-on type employing a germanium *p-n* alloy junction. This new cell features fast rise and decay characteristics, an illumination sensitivity of 0.2 microampere per footcandle, and a power-dissipation capability of 0.025 watt. Spectral response of this type covers the range from about 3500 to 19000 angstroms. Maximum response occurs at about 15000 angstroms. The 7223, therefore,



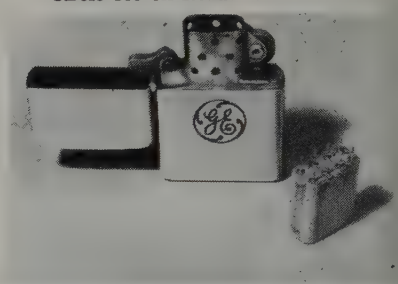
has high sensitivity to red and infrared radiation as well as good response in the visible region of the spectrum. Ask for Tech Bul. 7223.

Circle 172 on Reader Service Card

Grid Spaced Relays

Schweber Electronics has announced immediate availability of the new General Electric GS (grid-spaced) relays. Already in stock are five of the new GS relay types. Schweber has been selected by General Electric to market these as samples for evaluation purposes. Among other extensive tests, a group of the relays were given a 3 million operation dry circuit test. The level was 2 micro-amps with a 1000 ohm contact resistance failure point. Relays were continuously cycled from 65°C to room temperature to 320°C., and no failures were reported.

Circle 188 on Reader Service Card



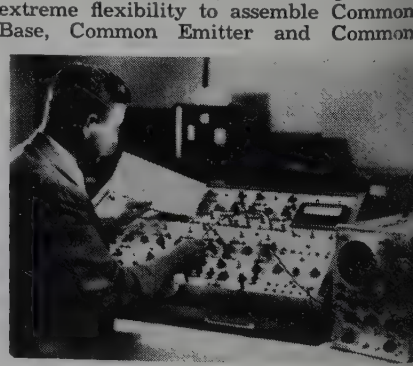
Miniature Transformers

A new line of miniature transformers engineered to customer specifications is now being offered by Palo Alto Engineering Company, West Coast transformer specialists. Designed for both commercial and military application, the new transformers are particularly useful in transistorized missile circuits. Size is so small that 20 units occupy only one cubic inch; weight is 175 units per pound. The manufacturer offers uncased, encapsulated or molded plug-in design.

Circle 154 on Reader Service Card

Transistor Circuit Synthesizer

A new electronic unit developed by National Electronics Laboratories called the Tranisitor Circuit Synthesizer readily enables designers to check the performance of contemplated circuit designs without the need for a "breadboard" of soldered wires. This instrument has four independent panels, each a transistor stage, and a master metering panel. The Transistor Circuit Synthesizer provides extreme flexibility to assemble Common Base, Common Emitter and Common



Collector circuit configurations. By combining two or more transistor panels through wires or plug-in shorting bars, circuits such as amplifiers, flip-flops, oscillators, and gates can be readily assembled.

Circle 157 on Reader Service Card

Transistorized D-C to A-C Inverter

Perkin Engineering Corp., announces a new transistorized Inverter with variable frequency *a-c* output. From a 12 V +10% —20% *d-c* input it provides an output of 115 V *a-c* 80 watts, single phase, square wave, with variable frequency between 57 to 63 cycles, ½ of 1% or ±.3 cycles for one hour, with variations no greater than 1% over four hours for temperature variations of 10°C. Enclosure is 300 cubic inches in volume and maximum weight is 14 lbs. Temperature range is 0°C to +50°C.

Circle 181 on Reader Service Card

Rectifier, Diode Tester

Equipment which rapidly performs five standard circuit tests for silicon, germanium and selenium metallic power rectifiers and signal diodes has been announced by Cedco Electronics, Inc. Designed primarily for use in manufacturers' production lines and laboratories, the analyzers test visual dynamic voltage-current characteristic, dynamic reverse current-leakage, dynamic forward voltage-drop, static reverse current leakage and static forward voltage-drop test. Ask for Bulletin MC-25.

Circle 169 on Reader Service Card

Silicon Rectifier

Sarkes Tarzian, Inc., Rectifier Division announce the addition of a new member to their low current silicon rectifier family. Designated as the "H" series, this "top hat" type, hermetically sealed silicon rectifier features a welded case and extra heavy duty junction for high reliability. Ratings range from 100 to 600 peak inverse volts and 750 milliamperes to 55°C.

Circle 185 on Reader Service Card

Medium Power Transistors

The General Electric Company has announced a new line of 30-volt, one-half ampere *p-n-p* germanium transistors for use in industrial and data processing equipment. The new transistors have been designed for medium power amplifier and low frequency, high current switching applications. The four models available in this line have received JETEC designations 2N524, 2N525, 2N526, and 2N527. They have a triangular lead arrangement and are housed in the JETEC TO-5 package.

Circle 173 on Reader Service Card

Power Transistors

Two new series of high current power transistors with typical current gains of 40 and 75 at 10 amperes are announced by Bendix Aviation Corporation. Maximum collector current rating is 15 amperes, and collector-to-emitter breakdown voltage ratings are 30, 40, 70, and 80 volts to eliminate burnout in high voltage applications. The corresponding collector-to-base breakdown ratings are 20 volts higher.

Circle 184 on Reader Service Card

Silicon Rectifier

A series of ten new silicon rectifiers (type 1N) is announced by Fansteel Metallurgical Corp. which are rated at a maximum *d-c* output current (at 50°C ambient) of 750 *ma*. These rectifiers are

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For further information circle No. 21 on Reader Service Card

How to increase your semiconductor yield ...with ALPHA UHP ultra high purity dot materials

Uniformity—in alloy composition and dot purity level—is significant in increasing alloy junction semiconductor yield.

To insure uniformity, all ALPHA dot materials—pellets, discs, washers, spheres and other forms—are produced by the "basic melt principle" as follows:

1. **Using metals** as refined as 99.999%+ purity, ALPHA carefully prepares the alloy in special, non-metallic vessels. (ALPHA offers all standard alloy combinations, fabricates special ones to your requirements.)
2. **ALPHA then analyzes** the alloy for major and minor constituents. Spectrographic analysis provides a further check on impurities.
3. **Found within specifications,** the melt is next fabricated on equipment used exclusively for ALPHA UHP* ultra high purity metals. The entire batch is processed at *one* time; equipment is specially allocated for each alloy combination; this safeguards against contamination, insures finished dot uniformity.
4. **As with the original batch,** the finished dots, too, are spectrographed for purity.
5. **Next, each finished lot** is rigidly inspected for conformity to dimensional and weight requirements. Measurements are made with the most precise balances and high-precision gauges.
6. **Lastly, all ALPHA UHP** dot materials are packed in protective, sealed containers.

The result of these rigid controls is ALPHA UHP ultra high purity dot materials. Their uniformity and correct constitution are important in controlling penetration and producing uniform junctions. *You gain increased semiconductor yield!*

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Wide Range of Fluxes . . . Soft Solder Preforms
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Circle No. 20 on Reader Service Card

7/32" diameter by 19/64" long, exclusive of leads, and are rated in steps from maximum peak reverse voltage of 50 volts to 600 volts inclusive. Maximum full load forward voltage drop (full cycle average at 150°C) is only one-half volt.

Circle 182 on Reader Service Card

Transistorized Power Packs

ERA Pacific, Inc., announces their high voltage, regulated semi-conductor power packs designated as the HYPAC line and providing output voltages in the range 1,000-10,000 V. *d-c* with current ratings in the milli-ampere range. These units feature small-size, light weight, high efficiency, low heat dissipation, fast transient response, low ripple content, instant warm-up time, short-circuit protection, and rugged long-life characteristics.

Circle 166 on Reader Service Card

Silicon Rectifier

A new type of diffused junction silicon rectifier developed by Bradley Laboratories, Inc., features built-in insulation that electrically isolates the semiconductor from the head and screw of the mounting stud. Thermal resistance is less than 2°C per watt. Two series are commercially available for 3 amp. (BY 400) and 10 amp. (BY 500) service at 100°C case temperature in voltage ratings up to 600 v. peak inverse.

Circle 177 on Reader Service Card

Transient Eliminator

Development of a new instrument, designed to protect transistor circuits from high-voltage transients, is announced by the Engineered Magnetics Division of Gulton Industries, Inc. The units are being produced in two models, EM 446 for airborne applications, and EM 472 for use in laboratory and ground support equipment. When placed in series with power sources they are claimed to absorb high-voltage transients and prevent their appearance at the output of the eliminator, thus protecting the transistor load.

Circle 167 on Reader Service Card

Metallized-Paper Capacitor

Specifically designed for transistor applications, 50 volt DC metallized-paper capacitors are now being produced by Aerovox Corporation. The units (indicated by arrow) are constructed in metal tubular case styles with glass terminal seals. Type P1232NNG units are capable of operation at temperatures from −65°C to 85° C at full voltage rating.

Circle 162 on Reader Service Card

Subminiature I-F Transformers

Wells Electronics Company of South Bend, Indiana, has announced production of a new "Weecoil" line of subminiature I.F. transformers for transistorized circuits. The complete "Weecoil 500" line consists of a single-tuned I.F., a double-tuned I.F., a diode filter I.F., a 7-pin I.F. for use with "drift" transistors, and an oscillator coil—all on bases that are approximately ½" square. "Q's" up to 165 can be obtained with regular components, and up to 200 if the transformers are unshielded.

Circle 150 on Reader Service Card

Transistorized Vibrator Replacement

A complete range of Univistors—transistorized direct replacements for mechanical vibrators that plug right into the vibrator socket—is now available from Universal Transistor Products Corp. The Univistor is an astable multivibrator used in conjunction with an external vibrator transformer to deliver *a-c* power output from *d-c* input. Since the external vibrator transformer is a part of the basic power supply circuit, the Univistor can be interchanged with a vibrator without any alteration in circuitry.

Circle 153 on Reader Service Card

Back Current Tester

Trans Electronics, Inc., announces the availability of a new test unit for back current, saturation or reverse testing of germanium or silicon semiconductors. Model BT 1 (Back Current Tester) is designed for quantity testing by minimum-skilled operators in quantity testing as well as for the skilled laboratory technician. Metering of both voltage and current is accomplished on six telephone-type lever key switches which select the desired range: (0-1000; 0-300; 0-100; 0-30; 0-10; 0-3). A three-position rotary switch selects the proper multiplier, V (volts), UA (microamps) and MUA (milli-microamps).

Circle 175 on Reader Service Card

Miniature Power Rheostat

Pioneering the field again, Ohmite Manufacturing Company announces its Model "E" Rheostat—a very small unit capable of 12½ watts dissipation at 40° C. It is only ⅞" in diameter, and extends 11/16" behind the mounting panel. Capable of operation in high ambient temperatures (with proper derating), this unit lends itself to military and aircraft applications. Ohmite is now stocking 23 different resistance values with linear winding. Rheostats with non-linear taper, tandem rheostats, or other features can be provided.

Circle 163 on Reader Service Card

Ceramic-Metal Seal

An exclusive new "Area Seal," developed by CFI Corp. gives high reliability to lead-through seals in multiple-terminal as well as single-terminal ceramic-metal composite units. A thin washer-like fitting around each terminal aids in making the unique seal. The seal can withstand processing temperatures above 900°C and remain completely vacuum tight, permitting the use of high melting-temperature braze alloys in fabricating ceramic-metal composites. The Area Seal distributes shock and vibration—thus lowering stress per unit area—and provides high mechanical strength and resistance to thermal shock.

Circle 168 on Reader Service Card

Pre-Assembled Components

Erie Resistor Corporation has announced the development of Erie "PAC" (Pre-Assembled Components) with wire leads for universal wiring, permitting virtually unlimited application for this highly versatile module. Formerly available only to manufacturers using printed wiring boards, the new Erie "PAC" enables manufacturers using point-to-point wiring methods to employ "PAC" without circuit redesign. Erie states the capacitor-resistor networks will offer capacitance values of 10 μμf to .01 μf in the ceramic dielectric, and from .01 μf to .1 μf in the mylar dielectric, with tolerance ranges of +100% —0%, ±20%, ±10%, ±5%. Resistance range of 10 ohm to 50 megohm; tolerances of ±5%, ±10%, ±20%.

Circle 161 on Reader Service Card

Miniature Plugs

A new miniature MS series of Cannon Plugs is now in production at Cannon Electric Company. Designated "KM", the new miniature is designed and qualified to MIL-C-25955 (USAF). Developed for

applications in aircraft, missiles and equipment the new KM features crimp-type, snap-in contacts to eliminate the soldering process and to facilitate field servicing. Included in the new aluminum-shell KM series are four basic endbell styles—short, straight, 45° and 90°. These may be used in any combination—on either plug or receptacle—to fit special space requirements. Hermetically sealed receptacles are also available.

Circle 151 on Reader Service Card

Voltage Calibrator

Exact Electronics, recently announced a new Type 100 Voltage Calibrator primarily designed for the accurate calibration of Oscilloscopes, *a-c* or *d-c* voltmeters, and measurement types of test equipment. The main feature of the Type 100 is the ¾% accuracy of the directly metered *d-c* or symmetrical 1 *kc* square-wave output. This direct metering of the output voltage gives accurate results under conditions of extreme external loading. Output range is continously variable from 0.02 volts to 100 volts.

Circle 170 on Reader Service Card

Transistorized Power Supply

Model 1515 transistorized power supply is one of a family of portable units protected by Robotec® a transistorized electronic circuit producing simultaneous current and voltage cutoff with an external short circuit. The Robotec circuit operates in thirty microseconds holding the power supply cut off until manually reset and reducing line input power to a negligible value. The power supply cannot be turned on if the short circuit persists.

Circle 171 on Reader Service Card

Transistorized Power Supply

A fully transistorized power supply is announced by Dressen-Barnes Corp. The unit has overload protection, and a regulation of .05%. High degree of freedom from spikes and transients. Short-circuit proof. Output is double fused. Ample cooling efficiency is provided. No derating is required for continuous operation. Output range of 0.5-36 V *d-c* at 15 amps, with full current available down to 0.5 V. Output is floating—either positive or negative can be grounded. Ripple: less than 1 Mv *rms;* recovery time: less than 50 μsec.

Circle 180 on Reader Service Card

Zener Diode Substitution Box

To aid the design engineer in rapid selection of zener diodes for experimental breadboard circuits, International Rectifier Corporation of El Segundo, California has developed *Zeniac*— a diode substitution box offering a selection of eleven basic one watt silicon zener diodes covering the range from 3.6 to 30 volts. The decade-type substitution box is housed in a compact, easily portable unit which may be inserted into any breadboard circuit . . . a turn of *Zeniac's* selector switch rapidly determines the exact diode required.

Circle 159 on Reader Service Card

Double-Diffused Silicon Transistor

A new double diffused silicon transistor 2N560, for use in military applications, has been announced by the Radio Division of the Western Electric Company, Inc. Made by the diffusion techniques this transistor features a maximum collector voltage of 60 V, a maximum collector saturation current of 0.1 μA at 20 V and a maximum collector capacitance of 12 μμf at 5 V.

Circle 164 on Reader Service Card

WHICH BENDIX TRANSISTOR IS BEST FOR THE JOB?

TYPICAL OPERATION AND MAXIMUM RATINGS OF BENDIX GERMANIUM PNP POWER TRANSISTORS

TYPE NUMBER	PRIMARY APPLICATIONS				MAXIMUM RATINGS				TYPICAL OPERATIONS			
	Audio	Push-Pull	Switch	Power Supply	Collector Voltage (a)	Collector Current	Thermal Resistance (b)	Junction Temp.	Current Gain (c)	Current Gain Ic	Circuit Gain	Power Output
					Vdc	Adc	°C/W	°C	—	Adc	db	Watts
2N234A	X				30	3	2.2	90	25*	0.5	30	2
2N235A	X				40	3	2.2	90	40*	0.5	33	2
2N235B	X				40	3	2.2	90	60*	0.5	36	2
2N236A	X				40	3	2.0	95	40*	0.75	33	4
2N236B	X			X	40	3	2.0	95	60*	0.75	36	4
2N285A	X			X	40	3	2.2	95	150*	0.5	39	2
2N399	X	X			40	3	2.2	90	40*	0.75	33	8 (e)
2N400	X			X	40	3	2.2	95	50*	1.0	36	6
2N401	X	X			40	3	2.2	90	40*	0.5	30	5 (e)
2N418			X	X	80	5	2.2	100	50	4.0	—	100 (d)
2N419				X	45	3	2.2	95	60*	0.5	—	5
2N420			X	X	40	5	2.2	100	50	4.0	—	—
2N420A			X	X	70	5	2.2	100	50	4.0	—	—
2N637	X		X	X	40	5	2.0	100	45	3.0	—	35 (d)
2N637A	X		X	X	70	5	2.0	100	45	3.0	—	70 (d)
2N637B			X	X	80	5	2.0	100	45	3.0	—	70 (d)
2N638	X		X	X	40	5	2.0	100	30	3.0	—	35 (d)
2N638A	X		X	X	70	5	2.0	100	30	3.0	—	70 (d)
2N638B			X	X	80	5	2.0	100	30	3.0	—	70 (d)
2N639	X		X	X	40	5	2.0	100	23	3.0	—	35 (d)
2N639A	X		X	X	70	5	2.0	100	23	3.0	—	70 (d)
2N639B			X	X	80	5	2.0	100	23	3.0	—	70 (d)
2N1031	X		X	X	30	15	1.5	100	40	10	—	75 (d)
2N1031A	X		X	X	40	15	1.5	100	40	10	—	125 (d)
2N1031B	X		X	X	70	15	1.5	100	40	10	—	250 (d)
2N1031C			X	X	80	15	1.5	100	40	10	—	250 (d)
2N1032	X		X	X	30	15	1.5	100	75	10	—	75 (d)
2N1032A	X		X	X	40	15	1.5	100	75	10	—	125 (d)
2N1032B	X		X	X	70	15	1.5	100	75	10	—	250 (d)
2N1032C			X	X	80	15	1.5	100	75	10	—	250 (d)

(a) Vce rating. Equivalent Vcb's are 20-50% higher. (b) Collector dissipation is the difference between the maximum junction temperature and the mounting base temperature divided by the thermal resistance. (c) hfe, AC current gain as noted with (*). All others represent hFE, DC current gain. (d) Square wave output power. (e) Push-pull output. (f) 2N1031, 2N1032 series have lugs. 2N677, 2N678 series have straight pins. 2N1029, 2N1030 series have flying leads.

There is a Bendix power transistor to help you get the right power and gain on *your* job. When you buy Bendix you enjoy extra quality at no extra cost: low leakage, life stability, high breakdown voltage, low thermal resistance, and controlled temperature variation. Our volume production enables immediate delivery on most models. For details or help on circuitry problems, write: SEMICONDUCTOR PRODUCTS, BENDIX AVIATION CORPORATION, LONG BRANCH, NEW JERSEY.

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Red Bank Division — Bendix Aviation Corporation

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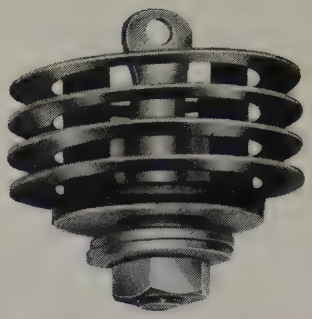
for maximum reliability

PREVENT THERMAL RUNAWAY



Prevent excessive heat from causing "thermal runaway" in power diodes by maintaining collector junction temperatures at, or below, levels recommended by manufacturers, through the use of new Birtcher Diode Radiators. Cooling by conduction, convection and radiation, Birtcher Diode Radiators are inexpensive and easy to install in new or existing equipment. To fit all popularly used power diodes.

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For further information circle No. 9 on Reader Service Card

New Literature

Fansteel Metallurgical Corp. Rectifier Capacitor Division makes available Bulletin 6.301A which describes the Type 2A rectifier rated for continuous output of 300 *ma* available in eight voltage ratings from 50 to 400 max. peak reverse volts; and Bulletin 6,302 which describes the new 750 *ma* silicon rectifiers of the 1N series made in voltage ratings from 50 to 600 volts.

Circle 101 on Reader Service Card

Brochure entitled, "Introduction to the Theory of Transistor Circuits," by J. J. Hupert, published by Communications & Electronics Foundation, is an outgrowth of a lecture given by the author on the above topic. Presentation is limited to small signal analysis and is intended to emphasize topics which are peculiar to transistor circuits. Proceeds from the sale of this publication are intended to be used for scholarships in electronics for deserving college students. Price $3.50.

Circle 102 on Reader Service Card

A Clip-on *d-c* milliameter for measuring tube and transistor circuit elements is described in the Hewlett-Packard Journal, June-July 1958. It makes the measurement of direct currents in low as well as high-impedance circuits as easy as a measurement of voltage, from a fraction of a milliampere to 1 ampere in six ranges. Further, and especially valuable in the transistor field, it introduces no *d-c* loading into the circuit being measured.

Circle 103 on Reader Service Card

Sorensen & Co. 1958 catalog describes their equipment which includes transistorized units designed for transistor circuit work. Among these are *d-c* supplies, *a-c* regulators, and *d-c* to *d-c* as well as *d-c* to *a-c* converters.

Circle 104 on Reader Service Card

Texas Instruments Inc. provides a brochure entitled, "Industry's Most Modern Electric Components." This brochure contains characteristics charts and case outline drawings of their silicon diodes and rectifiers, silicon transistors, germanium transistors, solid tantalum capacitors, precision carbon film resistors, and silicon resistors.

Circle 105 on Reader Service Card

Electronics Division, Iron Fireman Mfg. Co., provides Bulletin 600 and 780 which describes their current-sensitive and voltage-sensitive, respectively, micro-miniature type relays. These are balanced-armature, small hermetically-sealed enclosure units with miniaturization requirements.

Circle 106 on Reader Service Card

Chicago Standard Transformer Corp. Bulletin No. 535 describes their transistor type audio transformers, inputs, outputs, interstage and drivers. Electrical specifications are given for each type.

Circle 107 on Reader Service Card

Solid State Electronics Co. makes available a catalog sheet describing their Model S-100 silicon transistor sinusoidal oscillator having a frequency range of from 25 *cps* to 100 *Kcps*. Its features are microminiature and lightweight construction; it is temperature and supply stabilized and virtually immune to the effects of shock, vibration and acceleration.

Circle 108 on Reader Service Card

Hewlett-Packard Co. catalog sheet describes their 721A transistor power supply which features: 150 *ma* output, 0 to 30V *d-c* continuously variable, high regulation, ripple less than 150 *mv rms*, metered-output, and including a current limiter to prevent damage to transistors under test.

Circle 109 on Reader Service Card

NJE Corp. catalog sheet describes their solid state d-c transistorized power supplies which are short-circuit proof, provide total static regulation, low ripple, low-impedance, and low drift. Units for a wide range of voltage and current output are described.

Circle 110 on Reader Service Card

Texas Instruments Inc. provides a booklet containing speeches by various experts in the semiconductor industry on the occasion of the opening of their new plant. Valuable historical, technological and marketing information is contained in this booklet.

Circle 111 on Reader Service Card

Use of thermistors has been extended to new applications by Fenwal Electronics' development of beads to function continuously at 1200°F. These beads, presently available in bare form with attached leads and without glass coating, have a resistance of 250,000 ohms at 25°C, 0.7 Dissipation Constant, and 2 second Time Constant. They are completely stable within their temperature limits and can be used up to 1800°F with moderate stability. Designated BN52J1 and BN52L1, these thermistors are described in catalog EMC-2.

Circle 112 on Reader Service Card

Accurate Specialties Co., Inc., announces technical bulletin A-68, entitled Components for Semiconductors, which illustrates the uses and effects of the various impurities found in semiconductor alloying materials commonly used in device fabrication. Typical analyses specifically indicate type and extent of impurities found in Group 111 B "P" type impurity elements, Group V B "N" type impurity elements, Matrix elements and Alloying additives.

Circle 113 on Reader Service Card

Technical Product Information Bulletin No. 826 just released by Burroughs Corporation contains specifications and descriptive information on their line of Decade Counters containing Beam Switching Tubes and Nixie (R) indicators. Schematic drawings of typical associated circuits such as driver circuits, a one microsecond reset circuit, a one decade preset circuit, a *photocell driver* circuit and a remote Nixie read-out circuit are also provided.

Circle 114 on Reader Service Card

Simpson Electric Company announces a new Dual Range Therm-O-Meter with a self shielded core magnet meter movement. Simpson Model 389-3L has two ranges . . . a low range from —50° F. to 100° F. . . . and a high range from 100° F to 250° F. It can accommodate three leads simultaneously with separate readings through one selector switch on the front of the instrument. Overall accuracy is ±3° F. in any position, and at near center scale accuracy is within ±2° F. or better.

Circle 115 on Reader Service Card

Tempo Instrument Inc. offers its Engineering Bulletin No. 0558, describing the company's line of heavy duty, transistorized time delay relays. These relays are of subminiature design and employ transistor circuits—all moving parts except relay contacts have been eliminated. Models are available with highly accurate time delays from .01 to 60 seconds, or longer on special order. Operating temperature range is from —55 to 125 Deg. C. Units will withstand 50 g's shock; vibration up to 2000 cps at 20 g's.

Circle 116 on Reader Service Card

Electronic Research Associates', Incorporated, new catalog covers E.R.A.'s complete line of power supplies including transistorized inverters and converters, Transpac miniaturized power packs, power supplies for transistor applications, transistorized high current power supplies, transistor regulated DC power supplies, transistorized frequency changers and related models. The catalog includes technical descriptions, specifications, application notes, model numbers, and prices.

Circle 117 on Reader Service Card

A complete line of high quality, mass produced SonBlaster ultrasonic cleaners is described in detail in a new short form, four-page, two color catalog, available from The Narda Ultrasonics Coropration. The catalog provides detailed descriptions of the complete Narda SonBlaster stock line ranging from 35 watt systems up to 2.5 kilowatt systems, and with related SonBlaster transducers ranging in capacity from ⅜ gallon to a mammoth 75 gallons, comparing in quality, capacity, power, performance and appearance with ultrasonic equipment selling for two to four times as much.

Circle 118 on Reader Service Card

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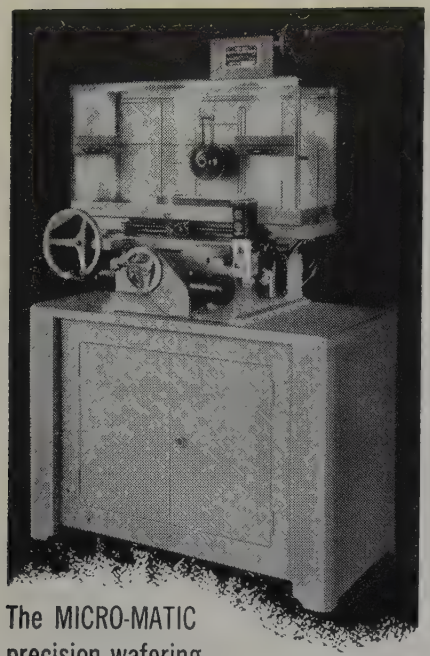

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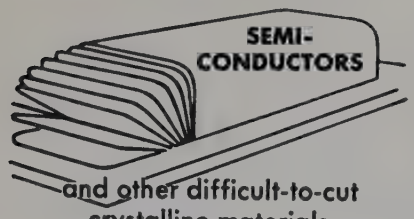

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Circle No. 26 on Reader Service Card

Electronic Research Associates, announces a new catalog sheet which describes the Company's new transistorized constant current generator Model CC2000. This model is a solid state design which provides constant current up to several amperes and is intended for various applications including transistor biasing and test, solenoid operation, traveling wave tube powering, electrochemical operations and similar uses.

Circle 120 on Reader Service Card

A new 84-page catalog describing the company's greatly expanded line of microwave and UHF test equipment and components has just been published by The Narda Microwave Corporation. The new 1959 edition of the Narda catalog includes all of the recent additions to the Narda line, in particular the company's new broad band bolometers and *thermistors*, tuneable waveguide detectors, tuned pre-amplifiers and transistorized VSWR amplifiers, and laboratory and classroom training sets.

Circle 121 on Reader Service Card

Data for circuit designers interested in computers, telephony, control and pulse circuitry is provided in a new technical bulletin describing the Shockley four-layer bistable transistor diode. Circuit properties, action of the four-layer diode, switching times, characteristics and test circuits are described in this new "file-type" publication. Available from Shockley Transistor Corporation.

Circle 122 on Reader Service Card

E. R. A. Pacific, Incorporated, announces the availability of a new multicolor catalog sheet describing the Company's new line of HYPAC solid state high voltage power packs. This new catalog lists transistorized regulated designs producing high voltage outputs from either AC or DC inputs. The catalog sheet also includes technical description, specifications, model numbers and prices.

Circle 124 on Reader Service Card

New proprietary precious metal brazing alloys—Paloro, Nicoro 80 and Nicusil 3—are featured in a new catalog describing the complete line of Wesgo ultra high purity, low vapor pressure brazing alloys for vacuum systems. Available on request, Catalog #V-124, from Western Gold & Platinum Company.

Circle 127 on Reader Service Card

Specification Sheet 3066 (Electronic Measurements Co., Inc.), gives description, specifications, and characteristic curves for the Model 66 Voltage Limiter. The Voltage Limiter is used to protect transistors and other voltage-sensitive devices from damage due to voltage transients.

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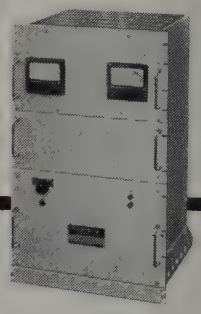

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For further data, write for Bulletin E-1M

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- Computer applications
- Control applications
- Gyrators
- Circulators
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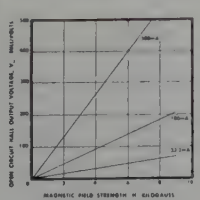
- Transducers

Typical Room Temperature Characteristics

Typical open-circuit Hall output voltage of an HS-51 HALLTRON vs. magnetic field strength for various values of control current, Ic.



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Circle 24 on Reader Service Card

A twenty page handy engineering catalog is available from Magnecraft Elec. Co., which includes illustrations, specifications and dimensional diagrams of the latest developments in *micro-miniature* rotary relays as well as extremely sensitive telephone type relays with a great range of contact combinations and long time delay.

Circle 125 on Reader Service Card

A new basic product catalog has recently been issued by the Communication Accessories Company. The company is a subsidiary of Collins Radio Company and manufactures Toroidal Coils, Filters, Magnetic Amplifiers, DC to DC Converters and Laminated Transformers. The new 20 page, catalog features illustrations of products, dimensional drawings, performance curves and general environmental information.

Circle 126 on Reader Service Card

A new 56-page manual just issued by the Stackpole Carbon Company, gives detailed property, application, and performance data on a wide range of carbon and graphite products. Detailed application information for a number of mechanical, chemical, electrical, and refractory uses are described and illustrated throughout.

Circle 129 on Reader Service Card

A new two-page technical bulletin describing the operation of the Model 1010 Variable Pulser, an instrument for converting any type signal source with a repetition rate up to 5 megacycles into standardized pulses of controlled amplitude and duration, has just been published by Technitrol Engineering Company. Briefly, the bulletin covers the operating principles of the Variable Pulser describing the operation of a modified Schmitt-trigger circuit, a high-speed flip-flop and a variable delay network.

Circle 130 on Reader Service Card

Bulletin 350A, an up to date version of the original four-page bulletin, includes new models and complete specifications of Electronic Measurements Co., Inc. power supplies. Models are listed according to application; transistor and lab work, automatic control, computer, and general utility.

Circle 131 on Reader Service Card

Arnold Magnetics Corp. announces Data Sheet M 8-1 which describes a line of miniature toroidal magnetic amplifier components which enable the designer to control the flow of power from a 400-cycle source to a load of up to 12 watts, AC or DC. The control source can be as little as 5 milliwatts of power. Power gains of up to 5000:1 can be obtained when external rectifiers are used. Matched cores are employed to provide optimum gain and linearity.

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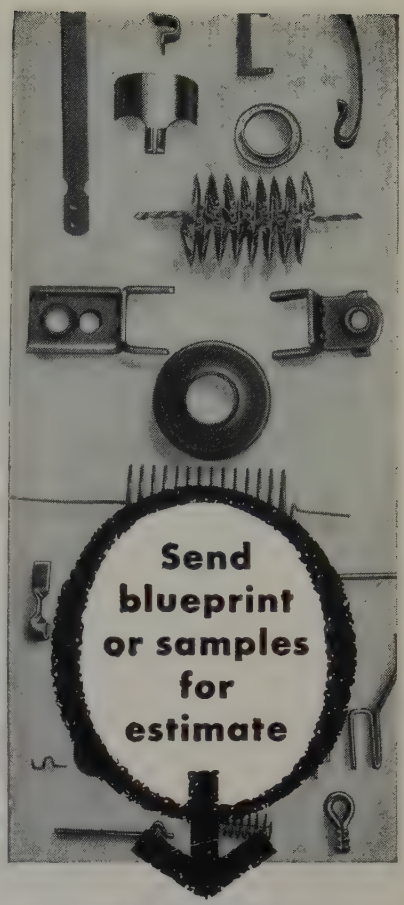

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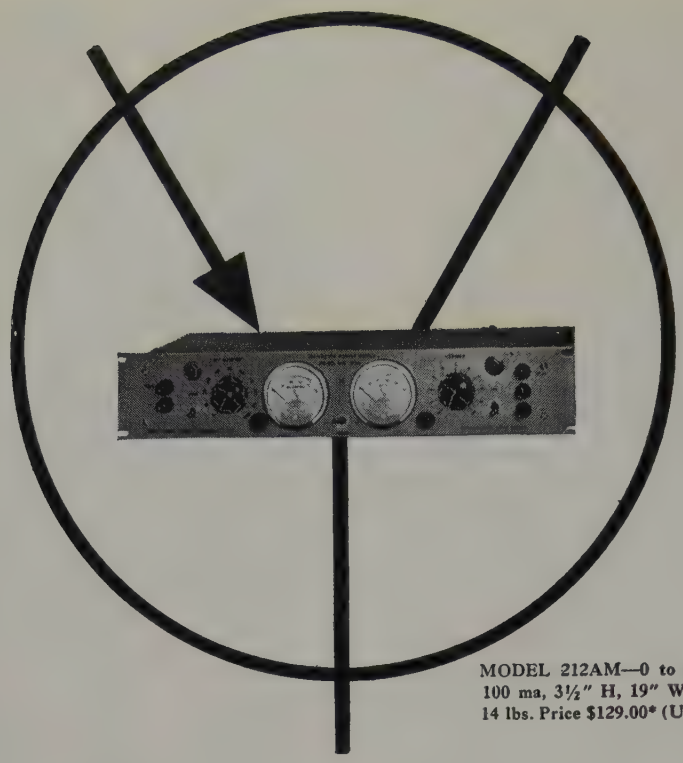

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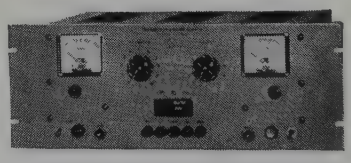

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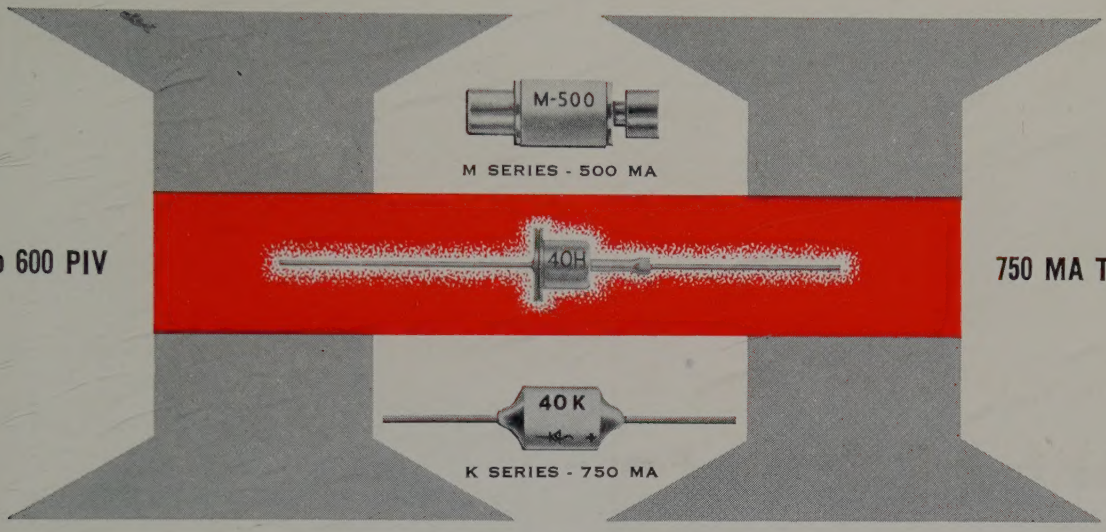

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10H	100	70	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	30	30	15
20H	200	140	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	30	30	15
30H	300	210	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	30	30	15
40H	400	280	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	30	30	15
50H	500	350	.75	.5	.25	1.875	1.25	.625	7.5	5.	2.5	30	30	15
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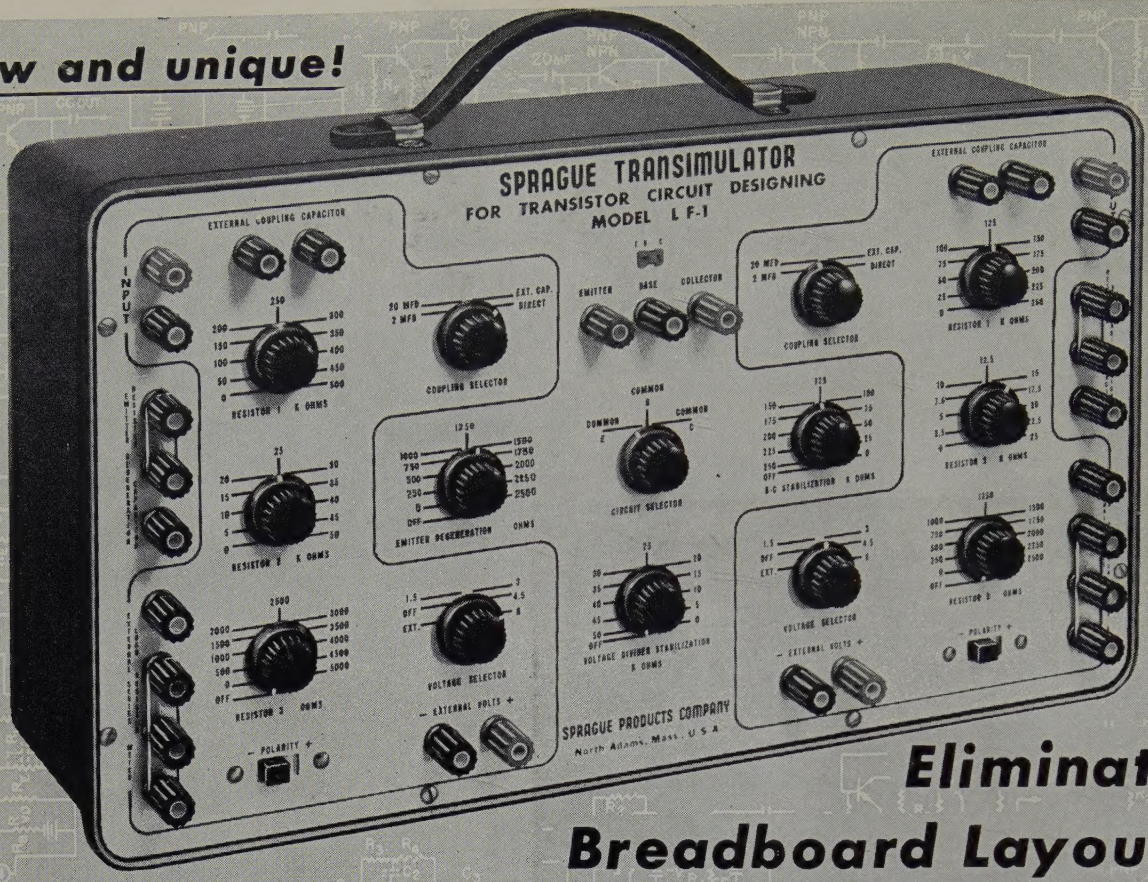

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